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AEROACOUSTIC ENVIRONMENT OF A STORE IN AN AIRCRAFT WEAPONS BAY

STRUCTURAL INTEGRITY BRANCH
STRUCTURAL MECHANICS DIVISION

MARCH 1977

TECHNICAL REPORT AFFDL-TR-77-18
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Flight tests were performed in which the sound pressure level distribution on the surface of a store was measured. The store was installed in the weapons bay of an F-111 aircraft and was flown at Mach numbers between 0.7 and 1.3 for altitudes of 3,000, 10,000, and 30,000 feet. Constant Mach number flights as well as accelerated ones were performed. There was a total of 21 microphones installed on the surface of the store. The resulting data from the microphones were used to determine equal level sound pressure level contours for the entire surface of the store. These contours revealed that the levels increase fairly

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uniformly for the first one-third of the store and then for the remainder of the surface they display areas of maximum and minimum sound pressure levels. For prediction purposes the contours were normalized and one general contour shape was developed. Also, a general spectrum shape is presented which gives the frequency distribution of the energy. Comparisons to past data showed good results.

FOREWORD

This research was performed by the Structural Integrity Branch, Structural Mechanics Division, Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio. This effort was conducted under Work Unit 75007139 in support of the Air Force Weapons Laboratory.

The work was performed by Messrs. L. L. Shaw and D. L. Smith of the Structural Integrity Branch, and Mr. G. A. Pizak of the Field Test and Evaluation Branch. This report presents only the aeroacoustic pressure results obtained from the microphones located over the surface of a store located in the bomb bay of an F-111 aircraft. The flight tests were conducted by the Armament Development and Test Center, Eglin Air Force Base, Florida.

The manuscript was released by the authors in November 1976 as a technical report.

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SECTION I

INTRODUCTION AND BACKGROUND

Aircraft weapon bays exposed to free stream flow generate an intense aeroacoustic environment in and around the bay. Experience has taught that the intensity of this environment can be severe enough to result in damage to a store, its internal equipment, or the structure of the weapons bay itself. In order to assure that a store and its internal equipment can withstand this hazardous environment and successfully complete their mission, they must be qualified to sound pressure levels representative of those experienced in flight. If the qualification test levels are too high, the store and its internal equipment will be overdesigned, resulting in unnecessary costs. However, if the levels are below the flight levels, the store or its internal equipment may catastrophically fail during performance of the mission. Thus, it is desirable that the actual flight levels be known with acceptable accuracy.

Based on the above requirement, the Air Force Weapons Laboratory (AFWL) requested the Air Force Flight Dynamics Laboratory (AFFDL) to determine the aeroacoustic environment encountered by a store carried in the weapons bay of an F-111 aircraft. AFFDL established a flight test program using an instrumented BDU-8/B (Bomb Drop Unit) to define this environment. The store was instrumented with 21 microphones and 21 static pressure ports. Only the dynamic pressure results are presented and discussed in this report. The instrumented store was installed in an F-111 aircraft weapons bay and flight tested by the

Armament Development and Test Center, Eglin Air Force Base, Florida. The flight test consisted of six flights in which data were collected at constant pressure altitudes of 3,000, 10,000, and 30,000 feet.

Detailed descriptions of the test article, instrumentation, test procedures, and data reduction procedures are given in Section II. Section III presents a detailed discussion of the results. Included in the discussion are effects of Mach number, longitudinal and circumferential location, and altitude on the aeroacoustic pressures. In addition, equal sound pressure level contours determined from the measurements over the store are presented and discussed. Finally, comparisons of measured and predicted levels are presented. Section IV offers a prediction method which enables the determination of the sound pressure distribution over a store in an aircraft weapons bay with a length to depth ratio near 6 for any Mach number or altitude. The results for the entire program are summarized in Section V.

The results of the program, sound pressure level distributions on the surface of a store in a weapons bay, can be utilized to define the aeroacoustic environment for the required qualification tests. These pressure distributions can be simulated in an acoustic test facility by such methods as source location, ducting, shielding, baffles, and absorption. This simulation provides a cost effective method for qualifying the store for an intense aeroacoustic environment.

SECTION II

DESCRIPTION OF TEST

1. Test Article

A BDU-8/B (Bomb Drop Unit) was installed in the weapons bay. The unit is 164 inches long, has an 18 inch diameter, and weighs [illegible] pounds. Figure 1 is a picture of the BDU-8/B installed in the F-111 aircraft weapons bay. The insert in the figure illustrates the location of the store in the weapons bay.

2. Instrumentation

The test instrumentation consisted of 21 Gulton MVA-212? microphones, 21 Bell & Howell ± 5 PSI Pressure Transducers and 1 Bell & Howell 15 PSI Pressure Transducer. The locations of the microphones and the ± 5 PSI Pressure Transducers are shown in Figure 2. The signal conditioning and recording equipment were located inside the BDU-8/B.

A block diagram of the complete data acquisition package is shown in Figure 3. The signals from the transducers were amplified by Intech Model A2318 Amplifiers and recorded on a 16 channel Leach Model 3[illegible]A FM Tape Recorder. Due to the limited number of recording channels only one-half of the microphones were recorded at a time. This necessitated each flight condition be flown twice. A 67-1-[illegible]-PAM Commutator was used to allow all the pressure transducers to be recorded on one channel of the tape recorder. A Datametrics type SP 105 Time Code Generator provided a 1000 Hz amplitude modulated

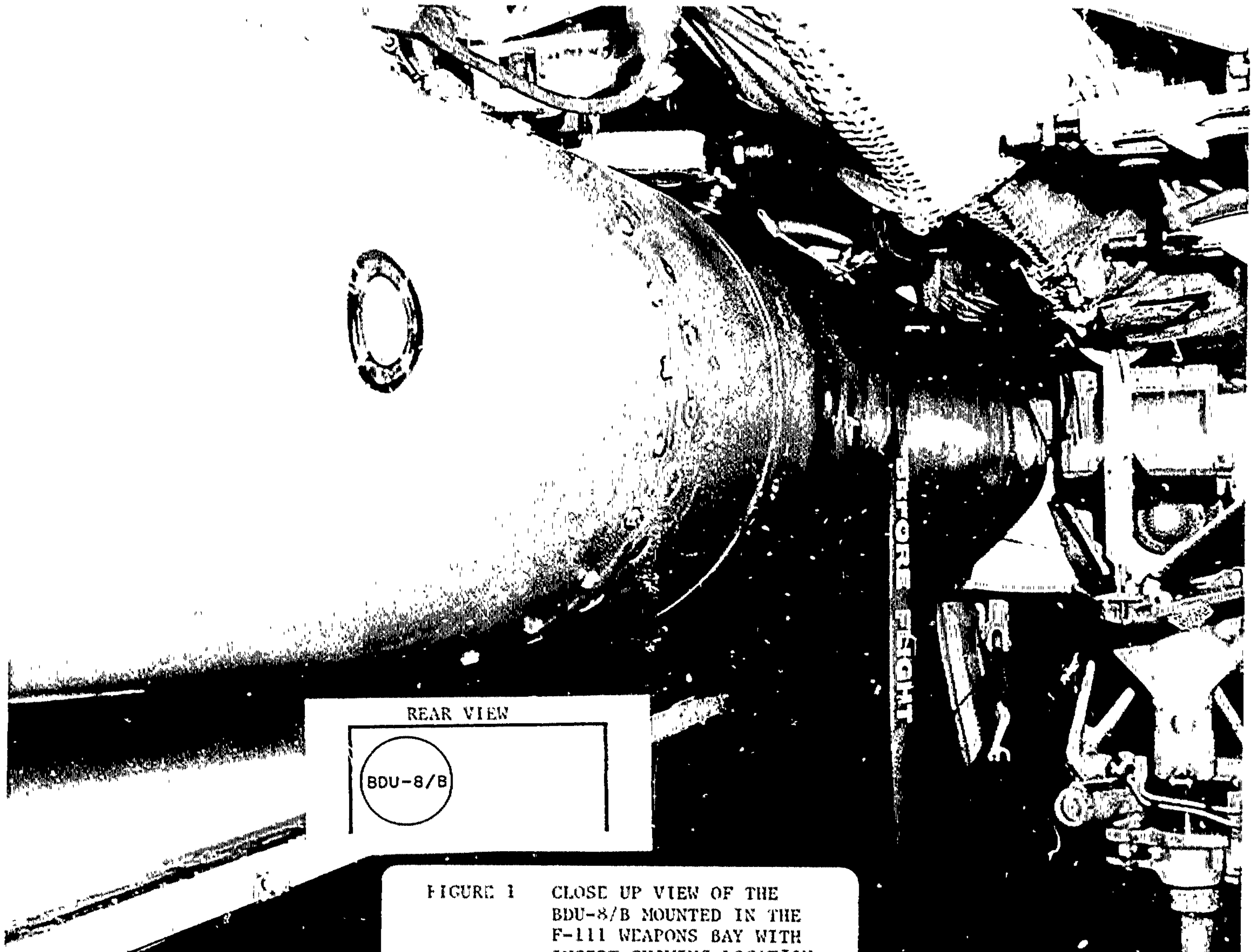

FIGURE 1 CLOSE UP VIEW OF THE BDU-8/B MOUNTED IN THE F-111 WEAPONS BAY WITH INSERT SHOWING LOCATION

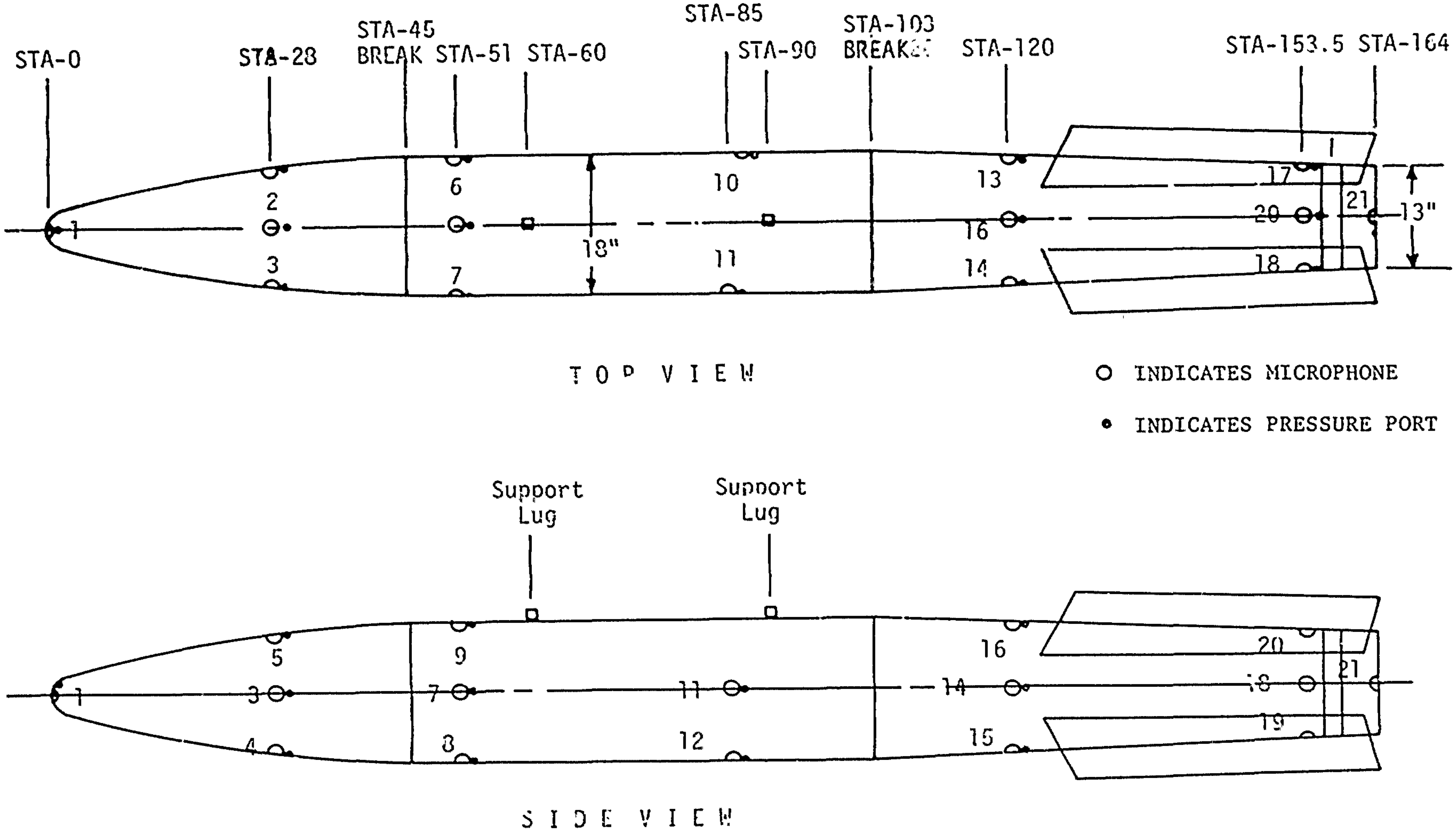

FIGURE 2 BDU-8/B MICROPHONE AND PRESSURE PORT LOCATIONS

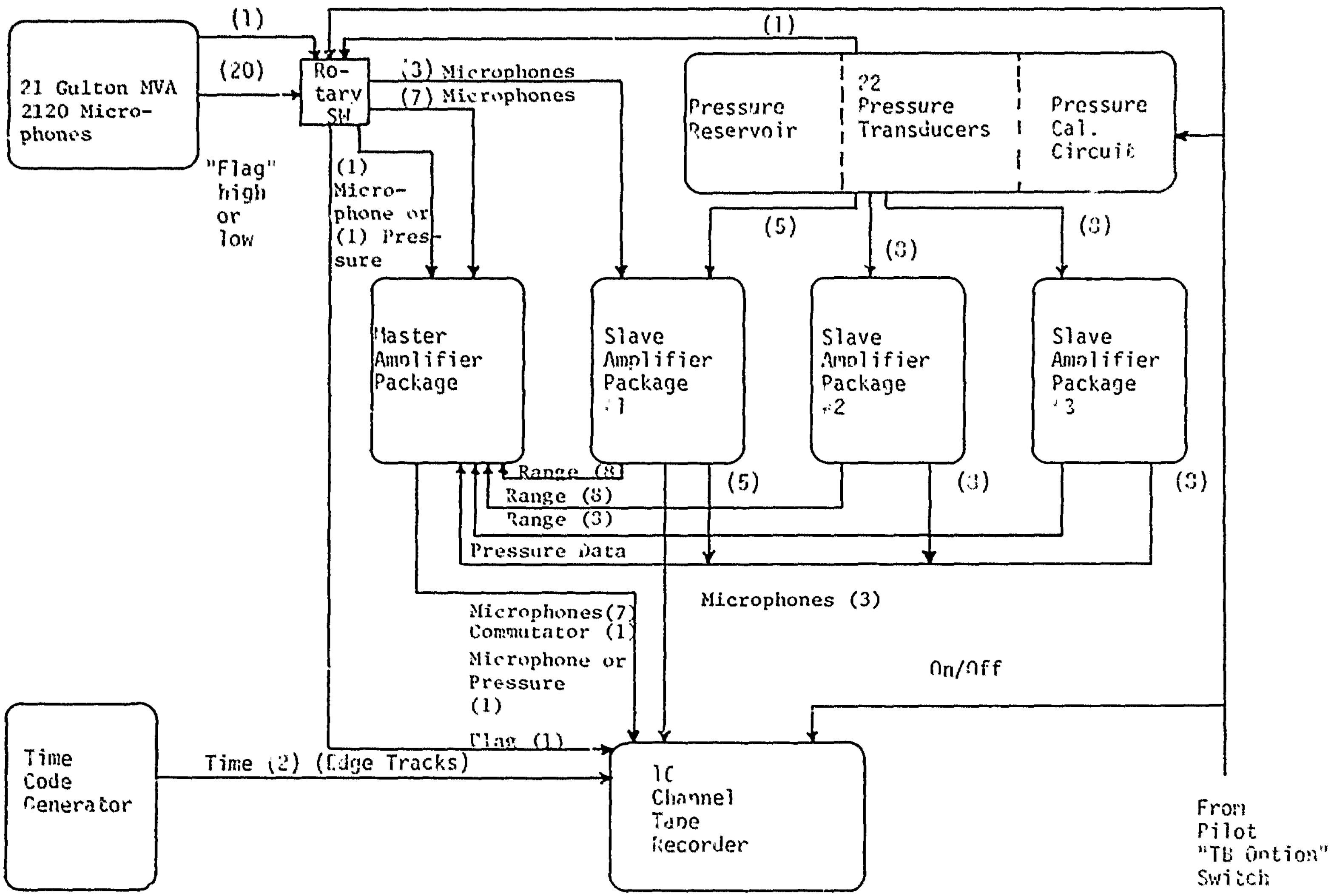

FIGURE 3 BDU-3/B DATA ACQUISITION SYSTEM

IRIG B Time Code which was also recorded. The instrument power was provided by the F-111's 28 VDC power.

3. Test Procedures

Flight data were obtained for constant pressure altitudes of 3,000 feet, 10,000 feet, and 30,000 feet during accelerated flight and constant Mach numbers. The Mach number ranges for the accelerated flights were approximately 0.75 to 0.97, 0.75 to 1.06, and 0.75 to 1.3 respectively. The constant Mach number runs were performed for each altitude at Mach numbers of 0.7, 0.8, 0.85, 0.9, and 0.95. All data were obtained in six flights. The flight tests were performed at Eglin Air Force Base, Florida. The data obtained in flight were recorded on an FM magnetic tape recorder for later reduction and analysis in the laboratory.

4. Data Reduction Procedures

Data reduction in the laboratory of the magnetic tapes recorded in flight consisted of overall sound pressure levels, one-third octave band spectra, and narrowband spectra. A General Radio Model 1921/26 Third Octabe Analyzer was used to calculate the sound pressure levels which were then plotted with a Gould Model 4800 plotter. The narrow-band spectra were generated digitally by a Raytheon 704 processor using a bandwidth of 1.83 Hz and a data sample length of 7.7 seconds.

SECTION III

DISCUSSION OF RESULTS

1. Introduction

In this section the results of the flight tests are presented and discussed. The effect of Mach number on the data is presented first. Variations over the entire surface of the BDU-8/B were determined but only those variations along the bottom of the store are presented in this report. The variation of the fluctuating pressure levels as a function of the longitudinal location are discussed next. Circumferential variation at four longitudinal locations is the third area discussed. The effects of flight altitude are the fourth area presented and include data from three locations on the store for each of the altitudes flown. Normalized equal sound pressure level contours developed from the measured data are then presented. These contours show the sound pressure level over the entire surface of the store for any altitude or Mach number. Contours for the one-third octave band modal frequencies as well as the overall levels are included. The measured levels are then compared to predicted levels where comparisons are made to data from the front, middle, and rear of the store. Narrowband analysis was performed on data from every microphone, however; only three typical spectra are presented. The last topic in this section is a comparison to past data. Acoustic data (Reference 15) obtained from the surface of a Pheonix missile being carried in an F-111 weapons bay was compared to the current data.

SECTION III

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2. Mach Number Variation

Mach number variations in the one-third octave band spectra from the six microphones located along the bottom of the BDU-8/B are shown in Figures 4-9. The data are for a constant 30,000 foot altitude. One-third octave band levels increased by 10 to 15 dB for most frequencies and locations on the bomb when the Mach number increased from .8 to 1.3. Previous wind tunnel and flight test results, References 2, 4, and 12-14, indicate comparable increases for similar flight conditions and cavity geometry. The spectra at the front of the bomb (microphone 1) are different than the spectra of other locations. The peak broadband level for the microphone 1 data occurs at a frequency less than 100 Hz while the spectra from the other locations generally peak at a frequency well above 100 Hz. A possible explanation for this difference lies in the fact that microphone 1 was located on the nose of the bomb and remained well out of the shear layer. The other locations along the botton of the bomb were close enough to the shear layer that it could impinge on the surface of the bomb and generate the high frequency energy that is displayed in the spectra.

The Mach number effects on the overall sound pressure level, derived from Figures 4-9, are shown in Figure 10. The overall levels are seen to increase at each location about 10 dB with a change in Mach number from 0.8 to 1.3. Increases in the overall levels of approximately 10 dB were anticipated since the levels are reported (Reference 16) to scale with the free stream dynamic pressure (q).

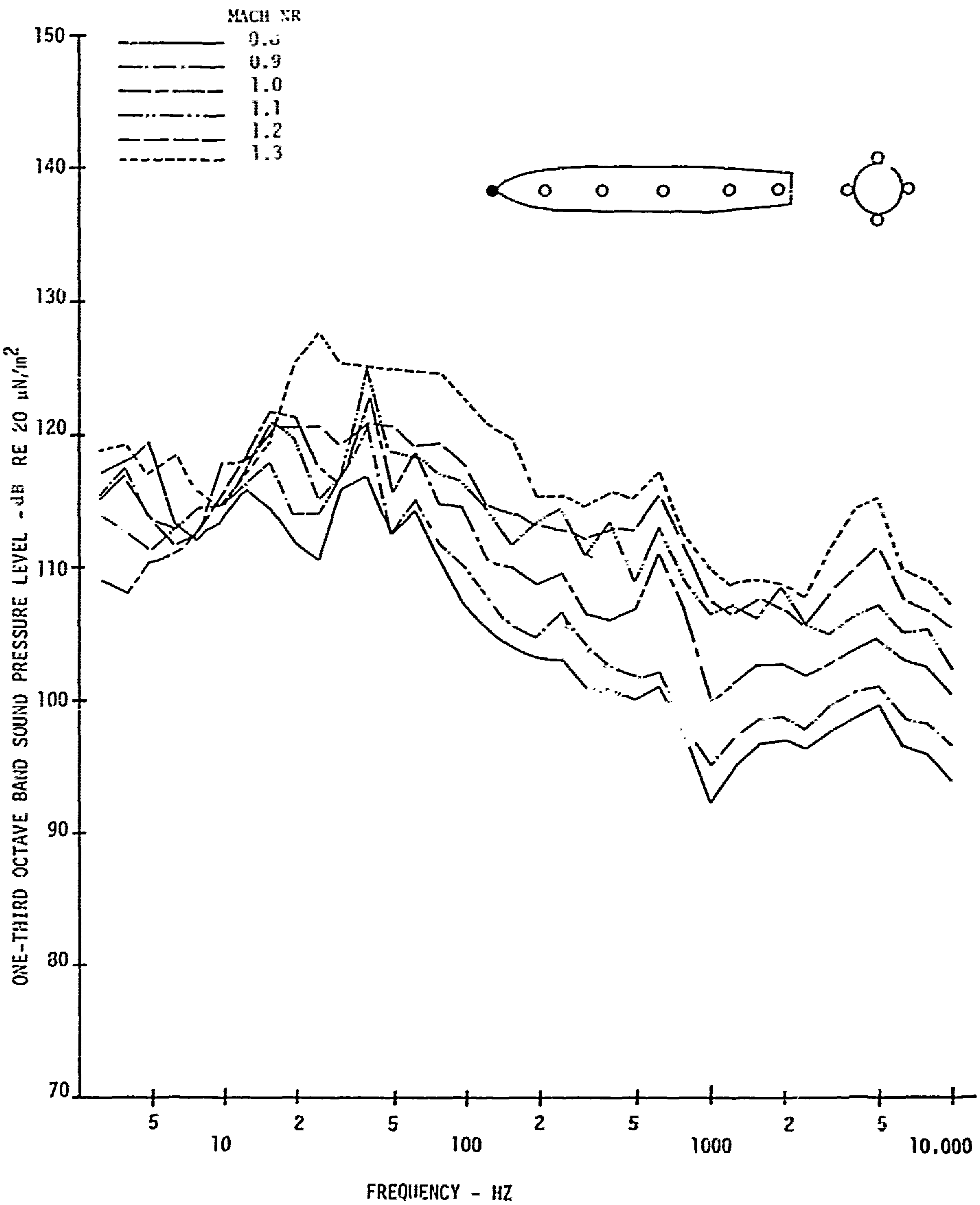


FIGURE 4 MACH NUMBER VARIATION OF ONE-THIRD OCTAVE BAND SPL SPECTRA FROM MICROPHONE 1 AT 30,000 FOOT ALTITUDE

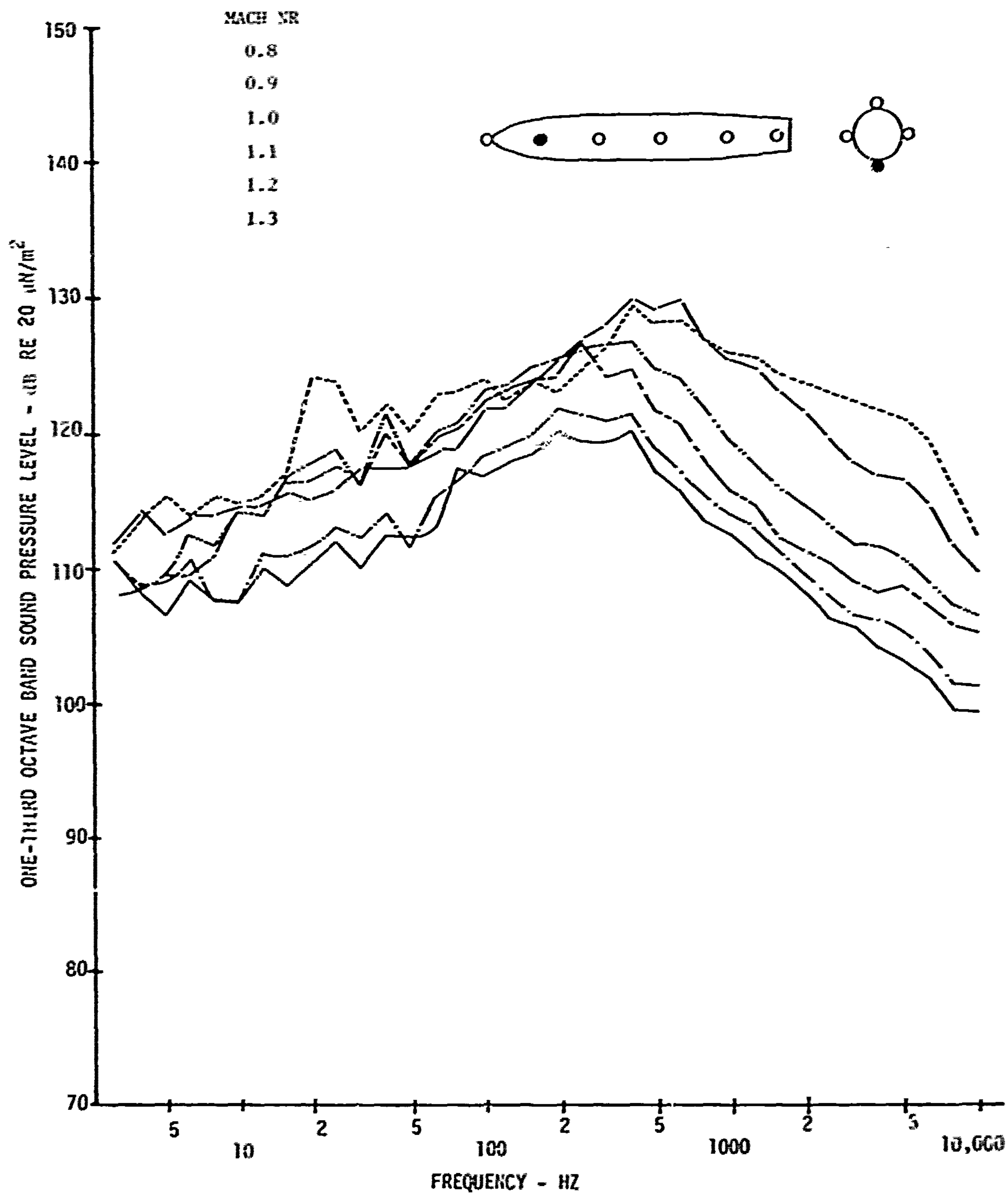


FIGURE 5 MACH NUMBER VARIATION OF ONE-THIRD OCTAVE BAND SPL SPECTRA FROM MICROPHONE 4 AT 30,000 FOOT ALTITUDE

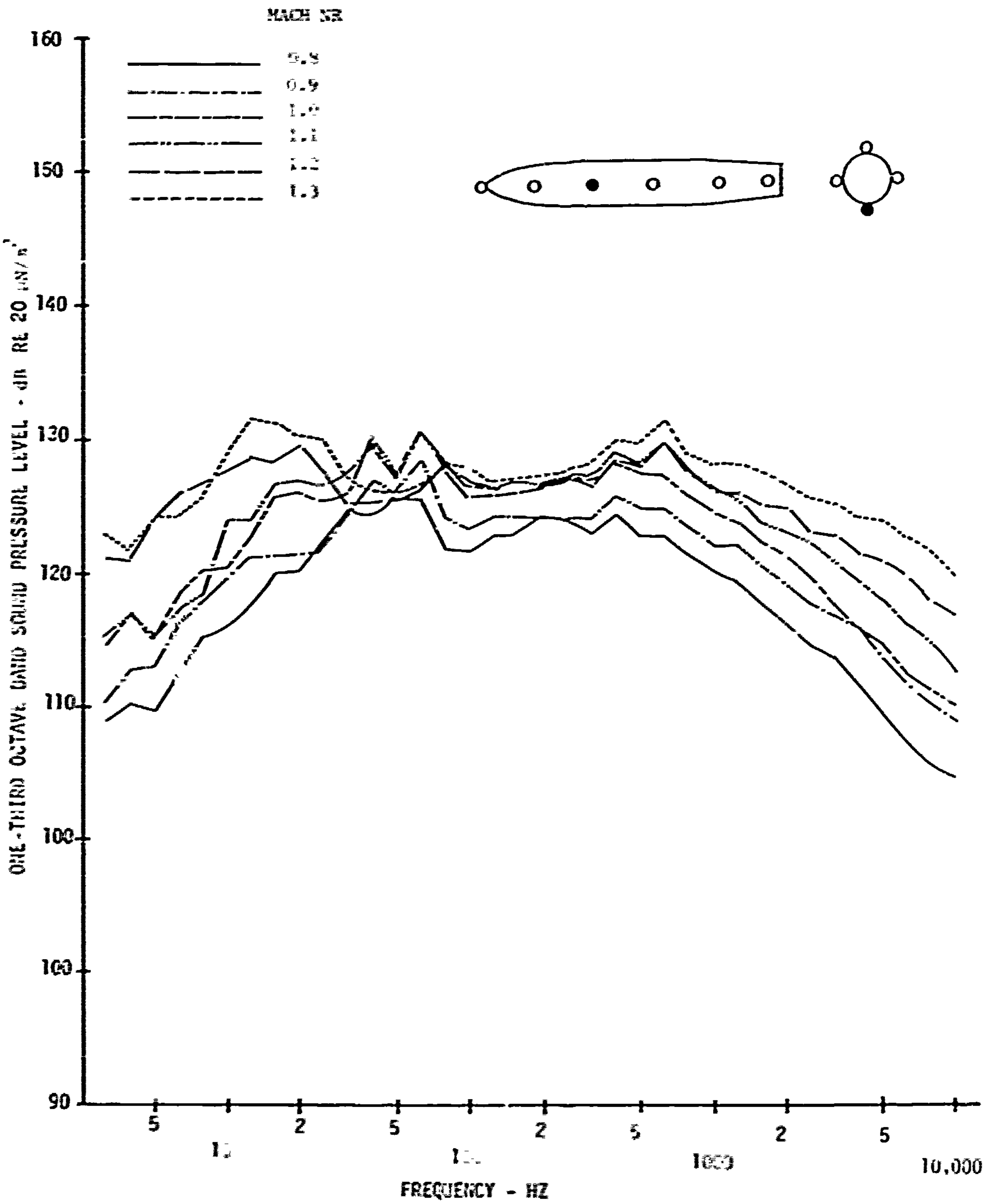


FIGURE 6 MACH NUMBER VARIATION OF ONE-THIRD OCTAVE BAND SPL SPECTRA FROM MICROPHONE 8 AT 30,000 FOOT ALTITUDE

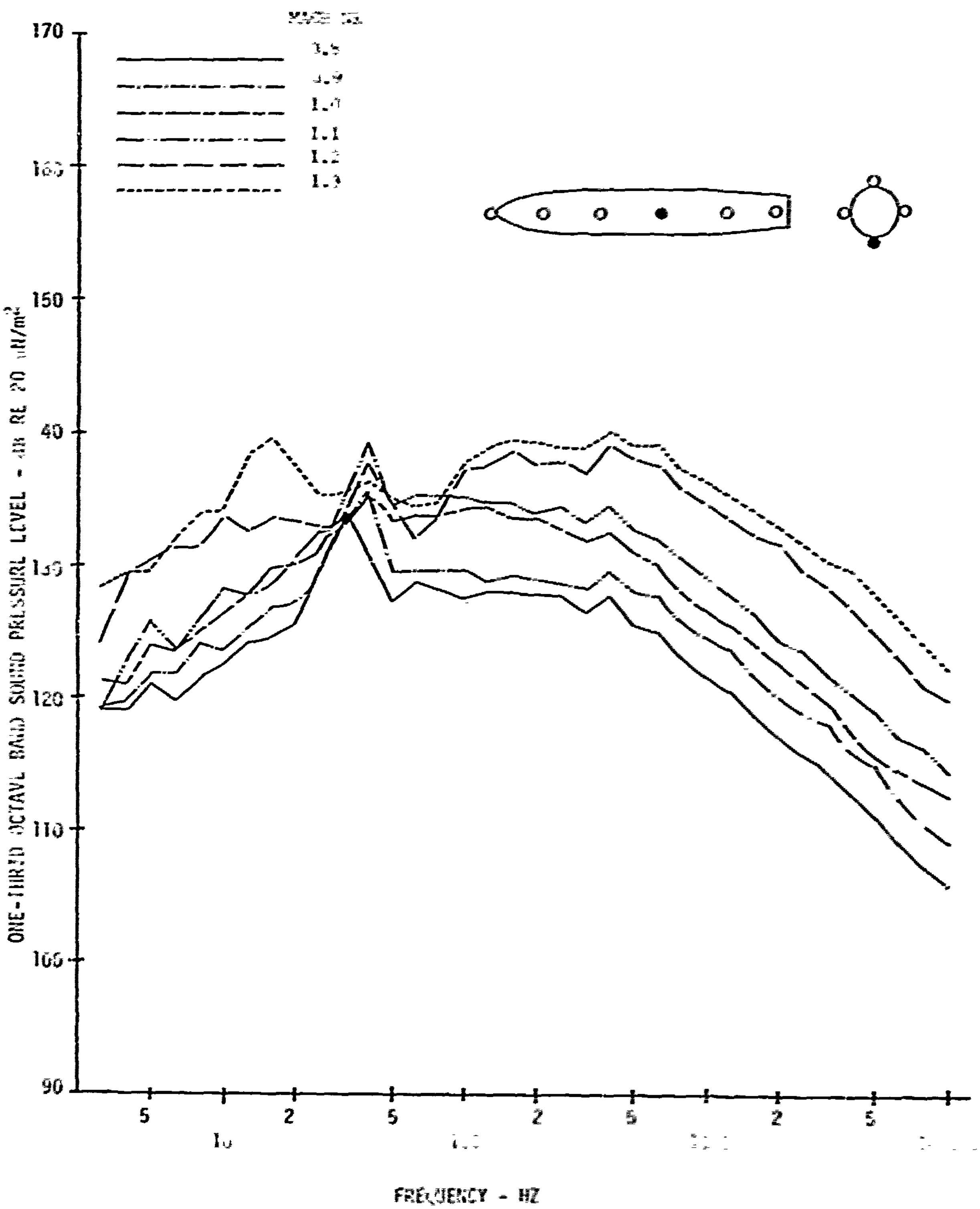


FIGURE 7 MACH NUMBER VARIATION OF ONE-THIRD OCTAVE BAND SPL SPECTRA FROM MICROPHONE 12 AT 30,000 FOOT ALTITUDE

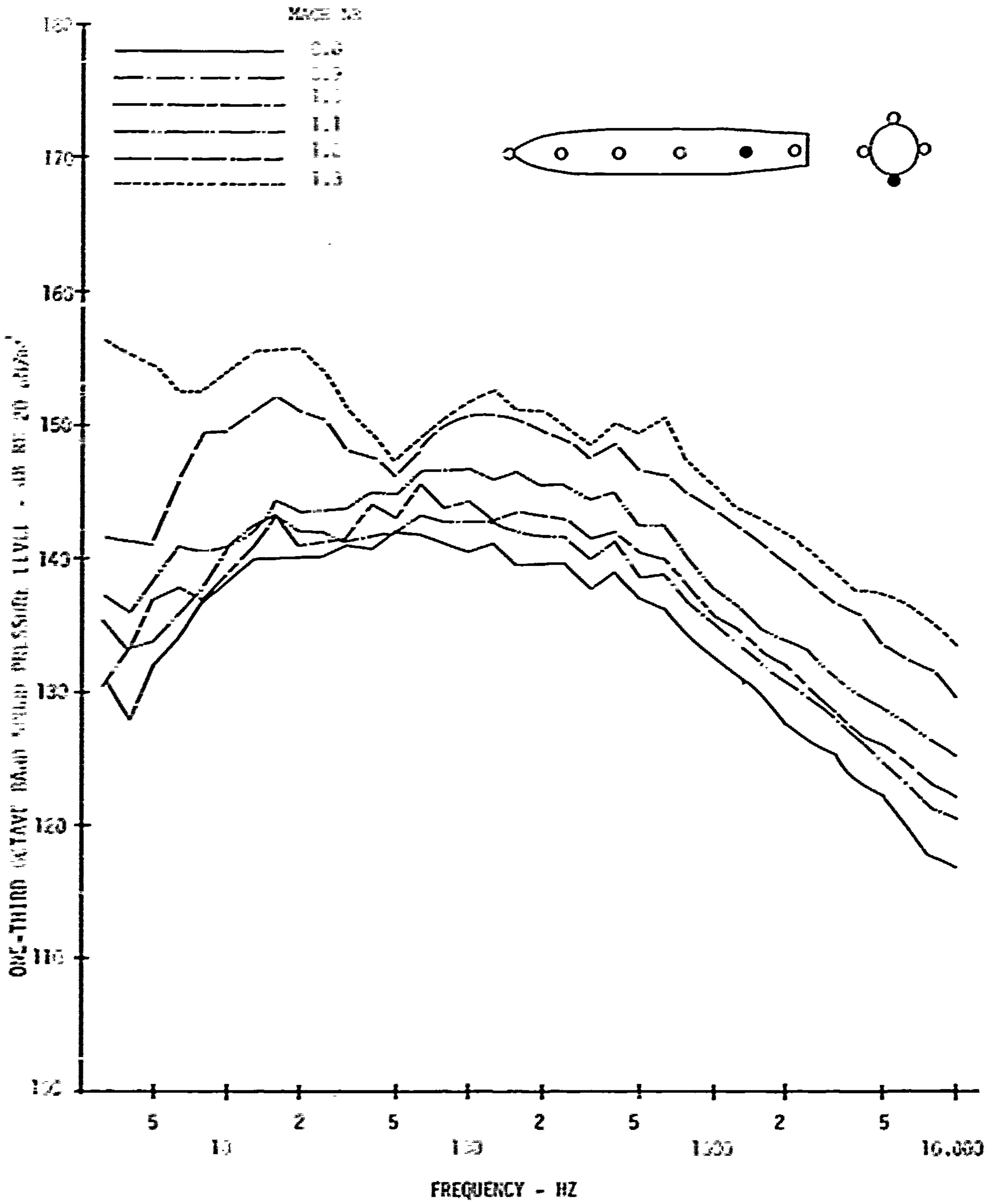


FIGURE 8 MACH NUMBER VARIATION OF ONE-THIRD OCTAVE BAND SPL SPECTRA FROM MICROPHONE 15 AT 30,000 FOOT ALTITUDE

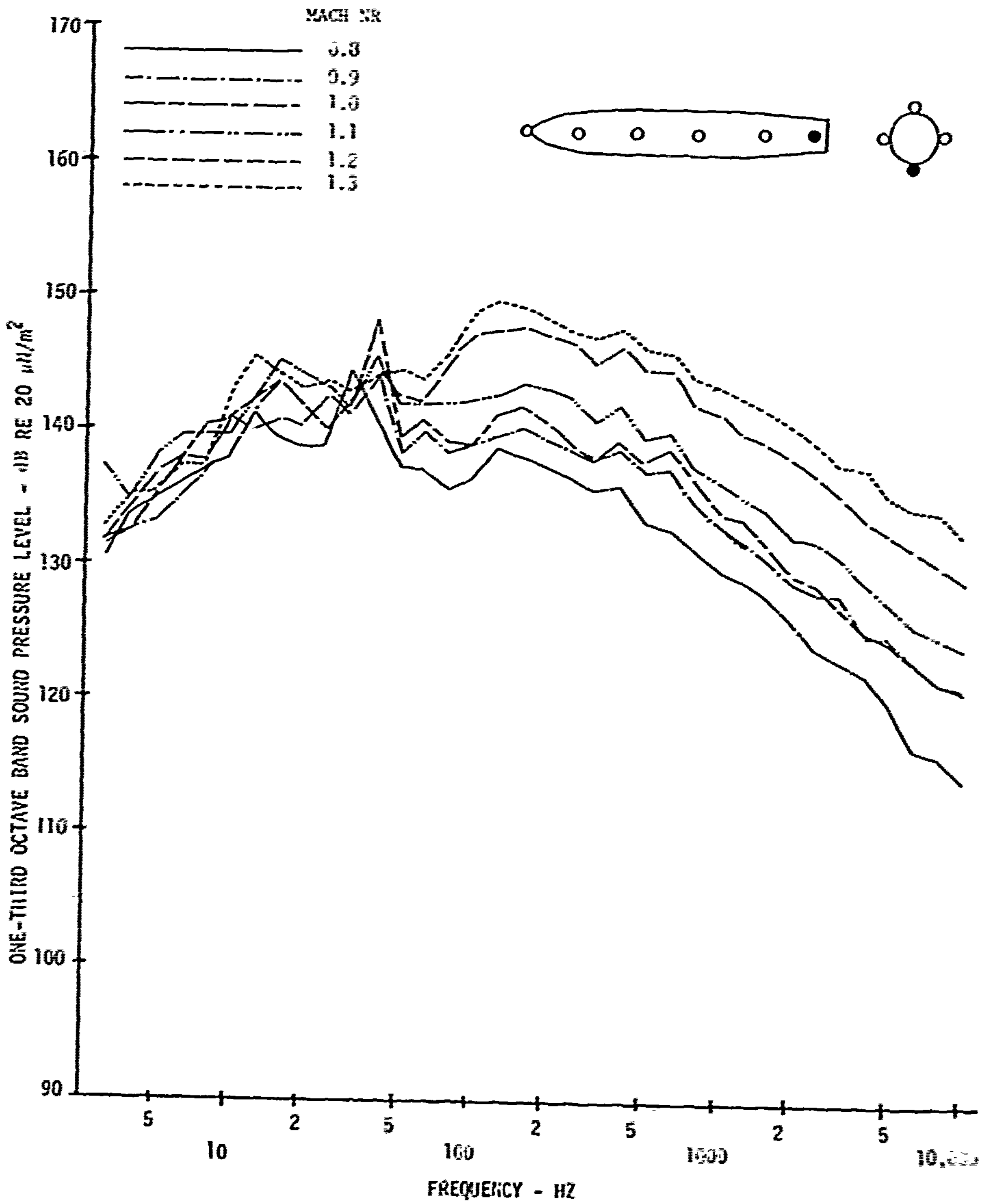


FIGURE 9 MACH NUMBER VARIATION OF ONE-THIRD OCTAVE BAND SPL SPECTRA FROM MICROPHONE 19 AT 30,000 FOOT ALTITUDE

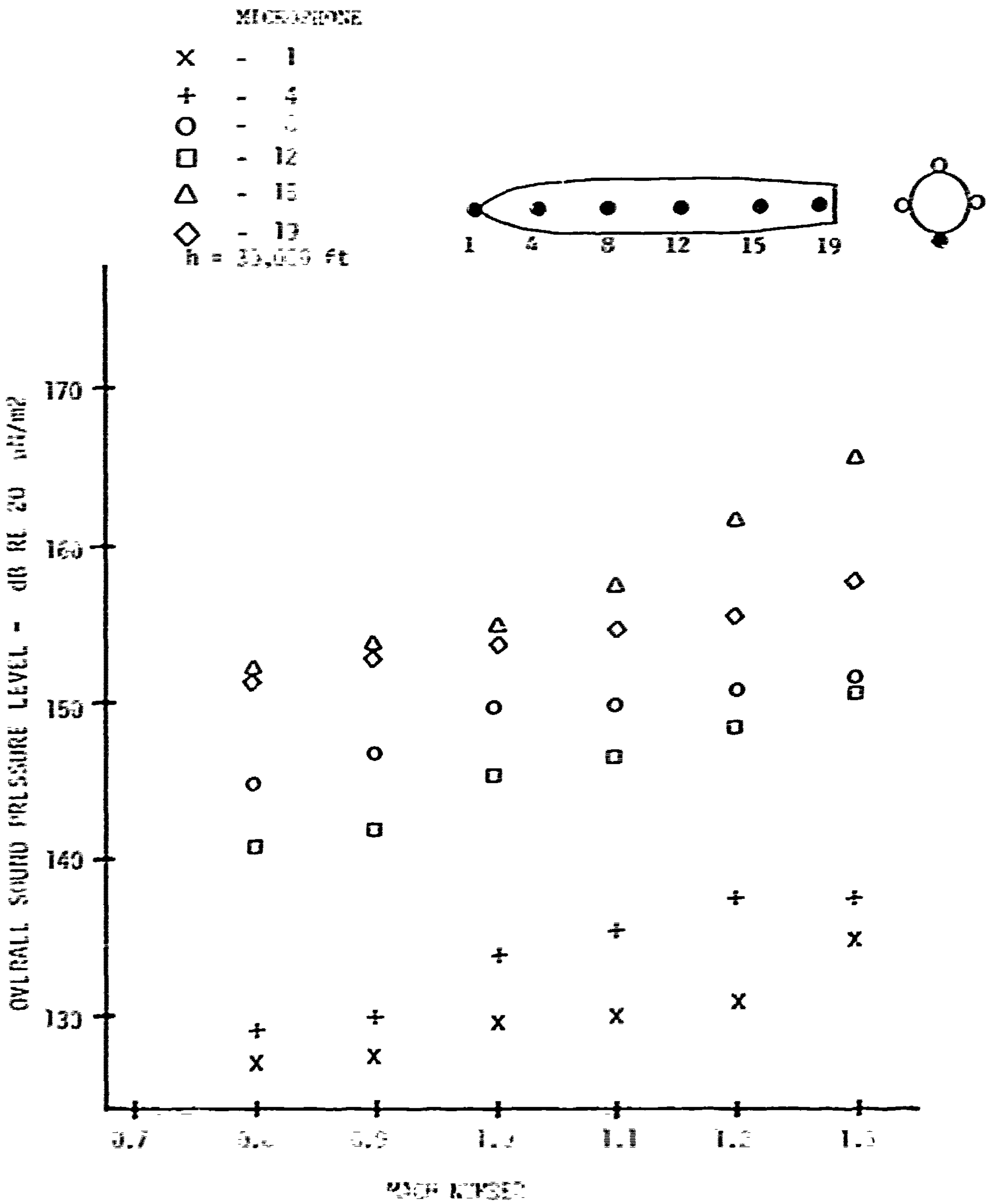


FIGURE 10 MACH NUMBER VARIATION OF THE OVERALL SPL

For a constant altitude, one predicts an increase of over 8 dB for the Mach number range investigated.

3. Longitudinal Variation

The overall levels shown in Figure 10 increase by approximately 25 dB from the front to the rear of the store. This increase is illustrated in Figure 11 for the entire spectrum. The spectra shown in the figure are for an altitude of 30,000 feet and a Mach number of 1.2. One-third octave band levels increase by as much as 35 dB. Increases on the order of 20 dB have been reported (Reference 16) from wind tunnel model and flight tests. A possible explanation for this difference is the current measurements were made on the surface of the store while most earlier data were obtained from transducers mounted in the cavity walls. This could have a significant influence on the differences being observed. A further explanation for this difference is that the F-111 weapons bay does not have clean, smooth walls as did the wind tunnel and flight test models and, in particular, the front wall of the weapons bay is not a well defined reflecting plane. Finally, relative cavity dimensions could have an effect on the variation from the front to the rear. At present it is not known whether the cavity scale size has a significant effect on the flow induced pressure oscillations. The comments above tend to explain the lower sound pressure levels observed at the front of the bay which thus explain the larger increase from the front to rear of the bomb.

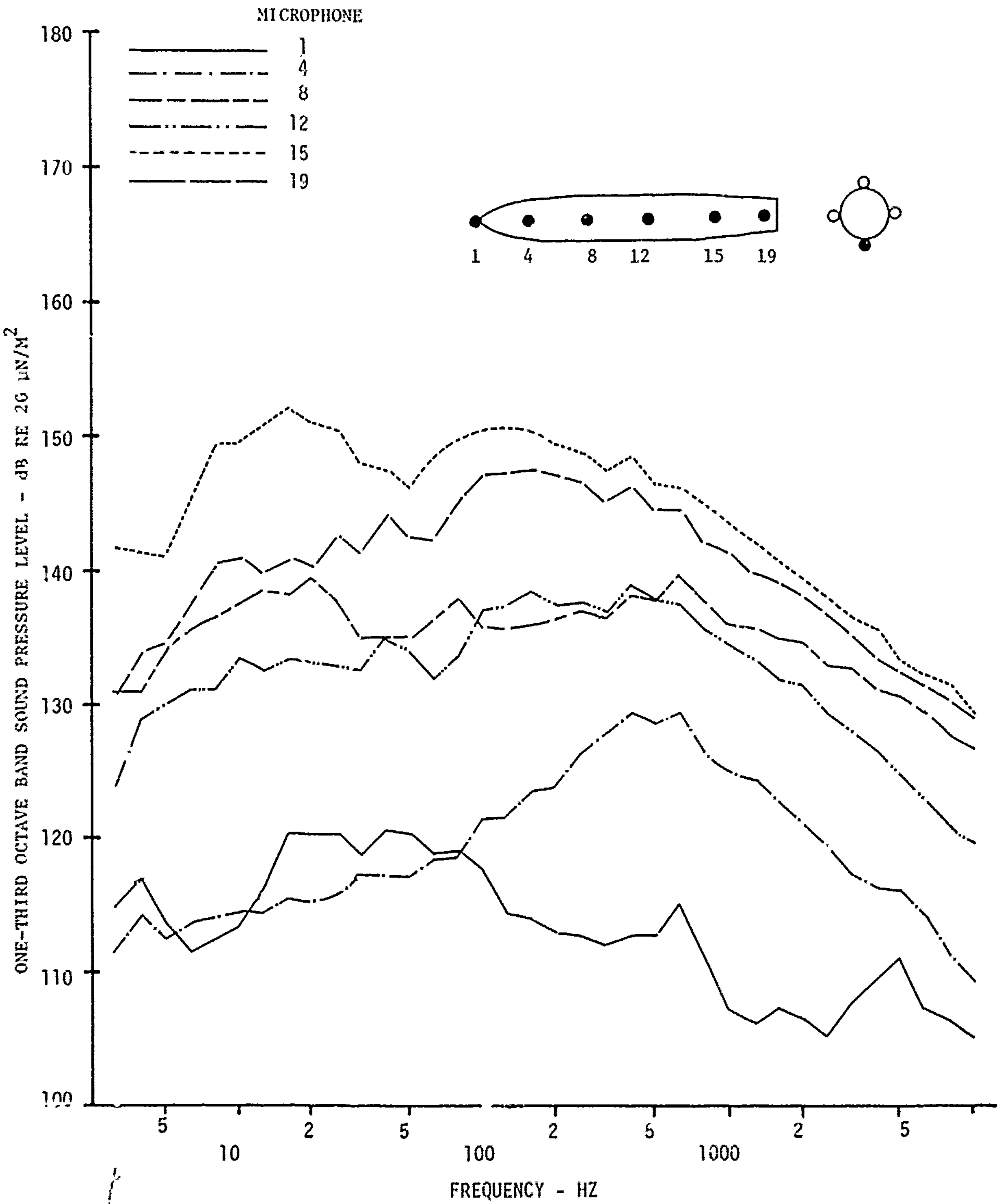


FIGURE 11 LONGITUDINAL VARIATION OF ONE-THIRD OCTAVE BAND SPL SPECTRA FOR A MACH NUMBER OF 1.2 AND A 30,000 FOOT ALTITUDE FOR VARIOUS MICROPHONE LOCATIONS

The highest pressure does not occur on the rear of the bomb; it occurs at some location shortly ahead of the rear. This is illustrated in Figure 11 where the spectrum from microphone 15, located approximately three feet from the rear of the store, is 2 to 10 dB higher than the spectrum from microphone 19, located six inches from the rear of the store. Previous results (Reference 3) indicated the same tendency. The results for the other Mach numbers and altitudes tested displayed similar trends to those discussed above.

4. Circumferential Variation

There were four locations on the BDU-8/B where microphones were located on each side, top and bottom at a given longitudinal location. Data obtained from these locations permitted an estimation of the circumferential variation of the SPL on the surface of the store. As shown in Figure 2, these locations were at stations (inches from the nose) 29, 51, 120, and 154. Figures 12 through 15 illustrate the circumferential variations for the various locations on the bomb. Several trends are apparent in the data. Figure 12 shows the variations between microphones 2, 3, 4, and 5 for an altitude of 30,000 feet and Mach number of 0.95. The narrowband energy at the cavity modal frequencies as defined by the Modified Rossiter equation (see section 8) is quite evident and is the highest on the side of the store towards the center of the weapons bay. The modal frequency amplitudes are lowest on the bottom of the store. At somewhat higher frequencies (above approximately 100 Hz) the sound pressure level on

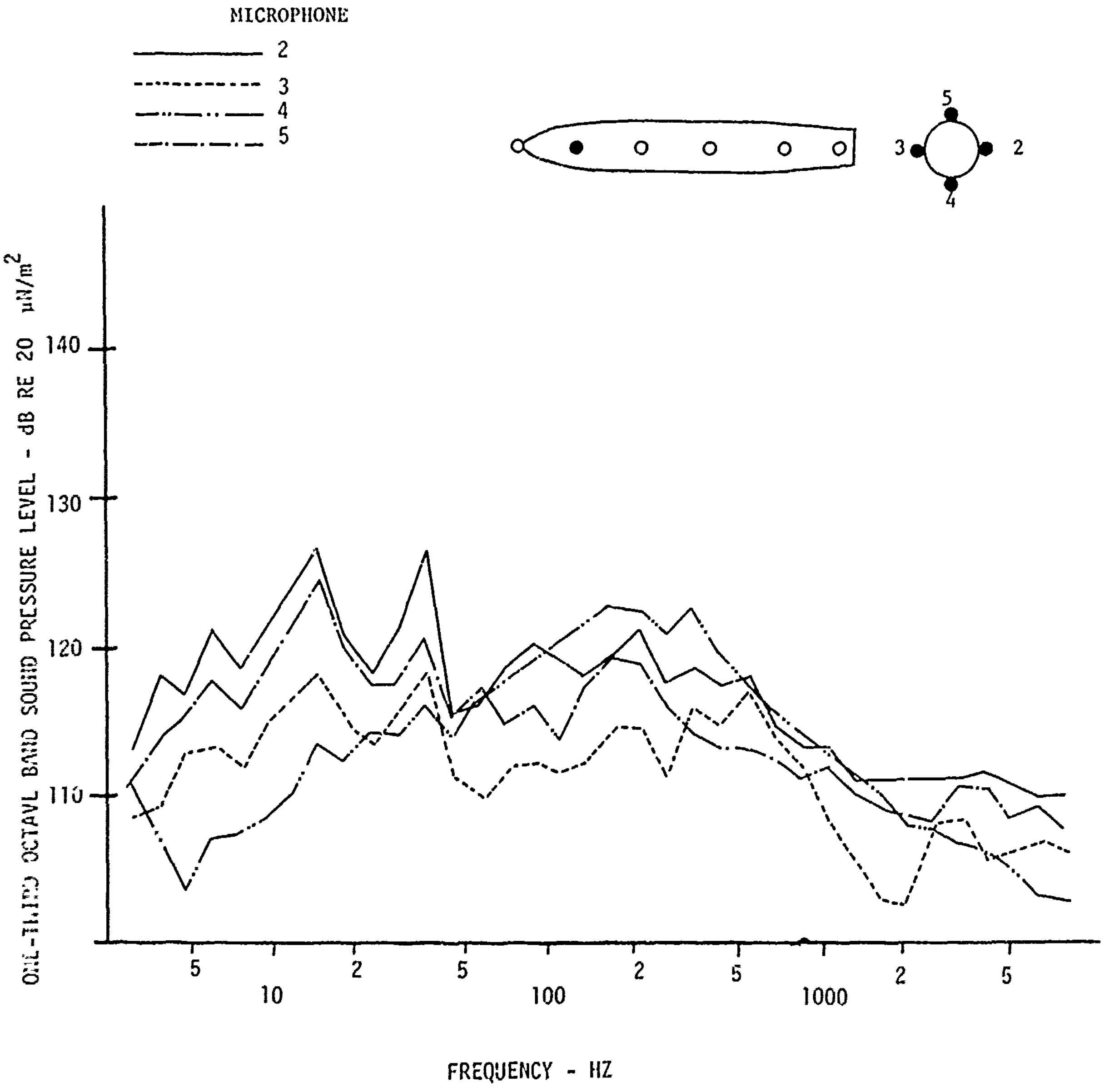


FIGURE 12 CIRCUMFERENTIAL VARIATION AT STATION 28 OF ONE-THIRD OCTAVE BAND SPL SPECTRA FOR A MACH NUMBER OF 0.95 AND A 30,000 FOOT ALTITUDE

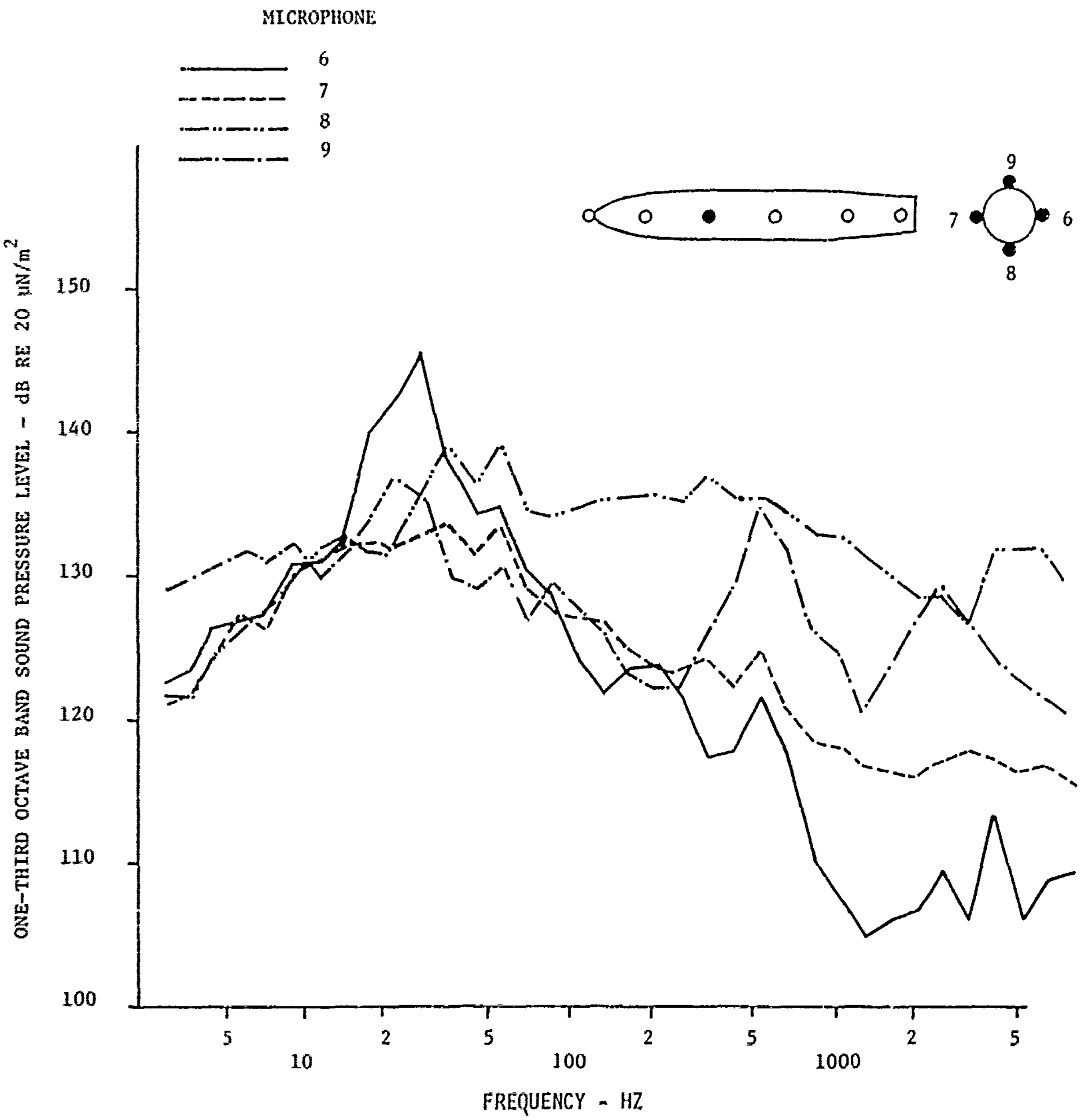


FIGURE 13 CIRCUMFERENTIAL VARIATION AT STATION 51 OF ONE-THIRD OCTAVE BAND SPL SPECTRA FOR A MACH NUMBER OF 0.95 AND A 30,000 FOOT ALTITUDE

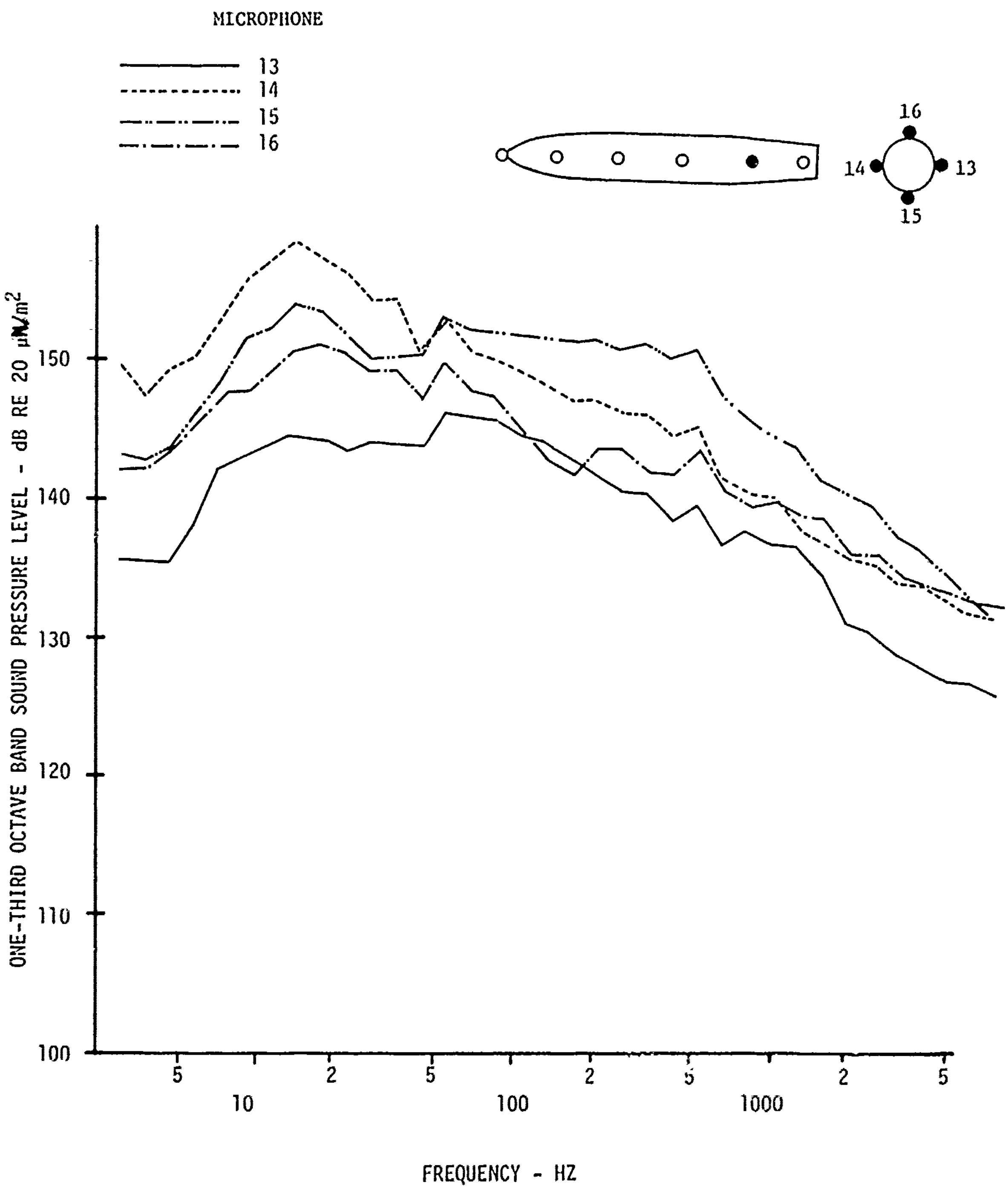


FIGURE 14 CIRCUMFERENTIAL VARIATION AT STATION 120 OF ONE-THIRD OCTAVE BAND SPL SPECTRA FOR A MACH NUMBER OF 0.95 AND A 30,000 FOOT ALTITUDE

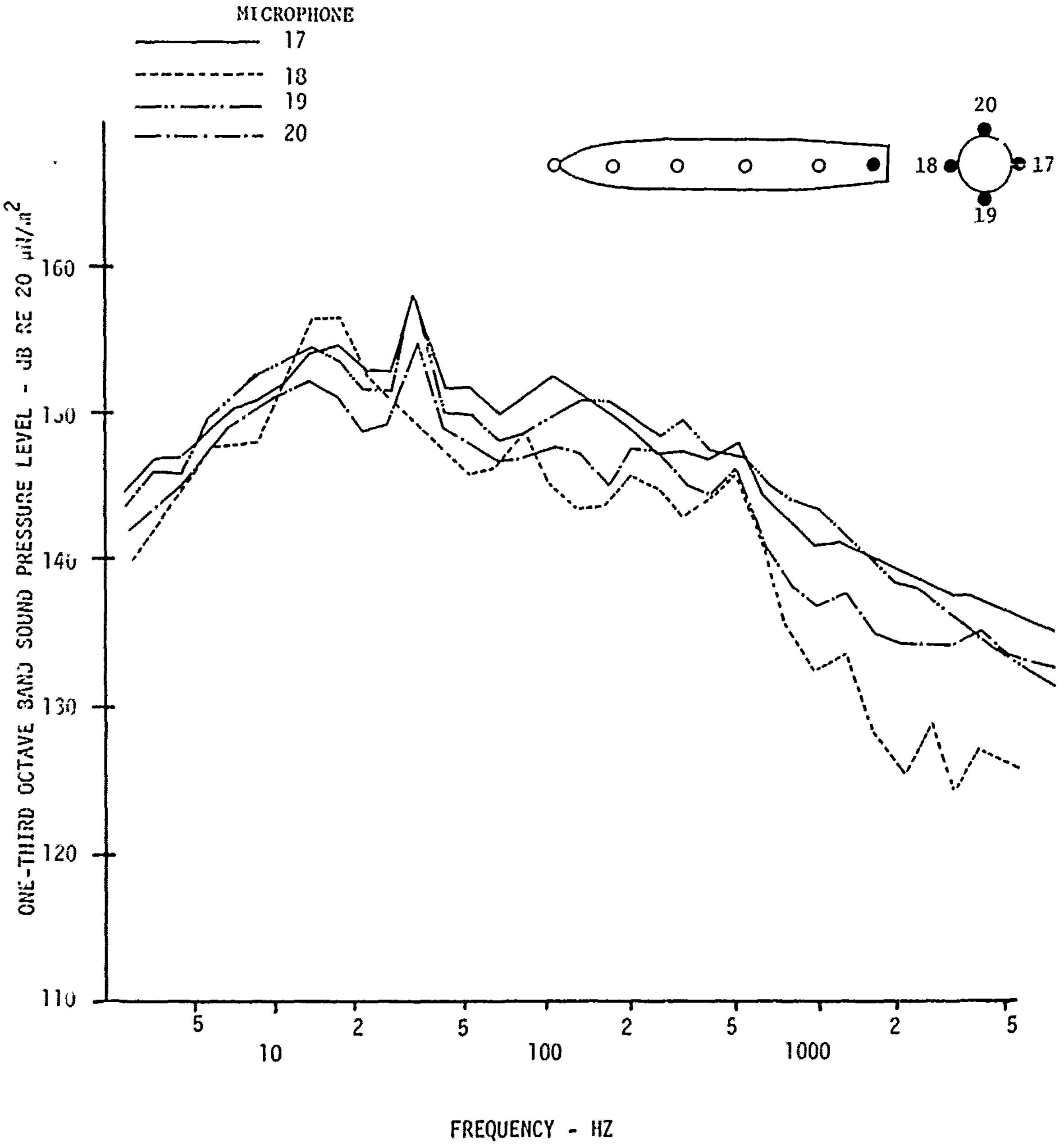


FIGURE 15 CIRCUMFERENTIAL VARIATION AT STATION 154 OF ONE-THIRD OCTAVE BAND SPL SPECTRA FOR A MACH NUMBER OF 0.95 AND A 30,000 FOOT ALTITUDE

the bottom side of the store increases above the other three locations; this may be caused by the shear layer impingement on the store.

The increased amplitude at the higher frequencies on the bottom of the bomb are even more evident in Figure 13 for microphone array 6, 7, 8, and 9 at station 15. The side of the store towards the center of the weapons bay still displays the highest level at the lower frequencies. Further back on the bomb at station 120, microphone array 13, 14, 15, and 16, the bottom of the store still shows the highest amplitude at the higher frequencies (Figure 14). However, the amplitude at the cavity modal frequencies appears to be the highest on the side of the bomb nearest the wall. This is the opposite of what was measured at the front of the bomb. No reason for this change is readily apparent. The array (microphones 17, 18, 19, and 20) near the rear of the bomb, station 154, displayed similar trends as those at station 120. That is, for the higher frequencies, the bottom of the bomb displayed the highest sound pressure levels and for the lower frequencies, the left side of the bomb displayed higher levels.

5. Altitude Effects

Investigators in the past (References 4, 16) have shown that in general the fluctuating pressure amplitudes for a fixed Mach number in an open cavity vary with the free stream dynamic pressure "q." However, it was shown in Reference 13 that there may be locations in the weapons bay (or cavity) which do not scale very well with q. Figures 16 through 18 present spectra for the three test altitudes

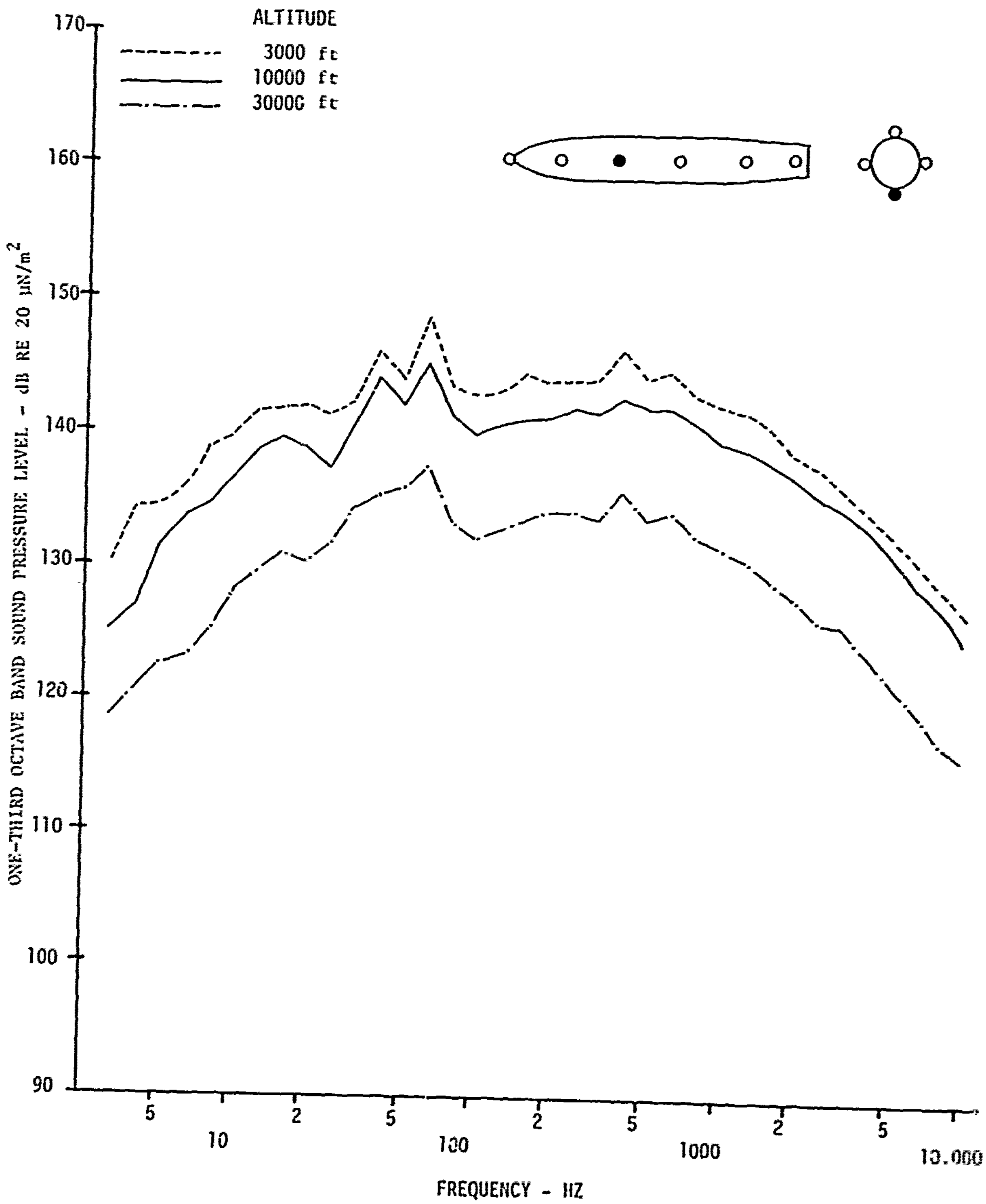


FIGURE 16 ALTITUDE EFFECT ON ONE-THIRD OCTAVE BAND SPL SPECTRA FROM MICROPHONE 8 FOR A MACH NUMBER OF 0.35

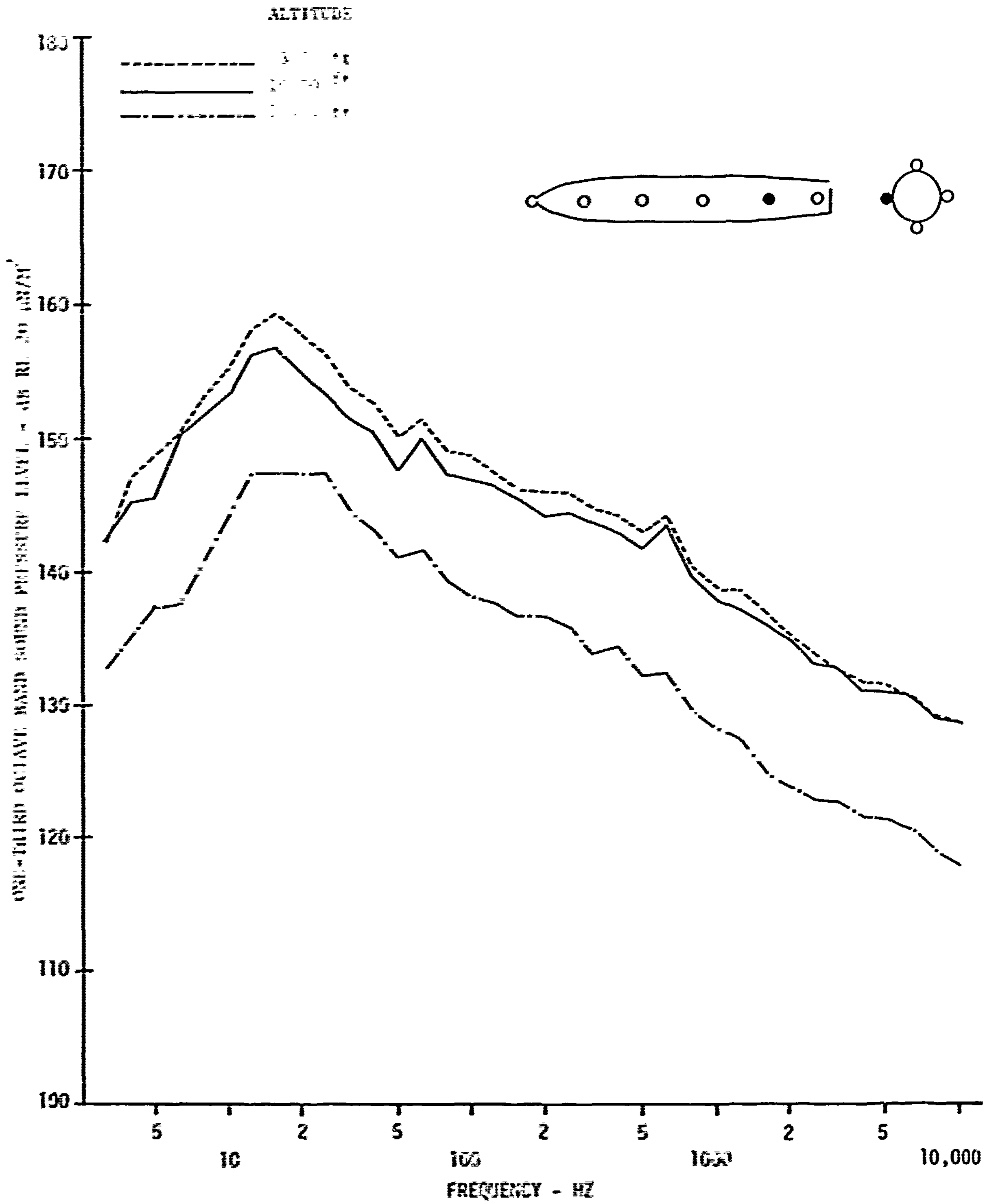


FIGURE 17 ALTITUDE EFFECT ON ONE-THIRD OCTAVE BAND SPL SPECTRA FROM MICROPHONE 14 FOR A MACH NUMBER OF 0.85

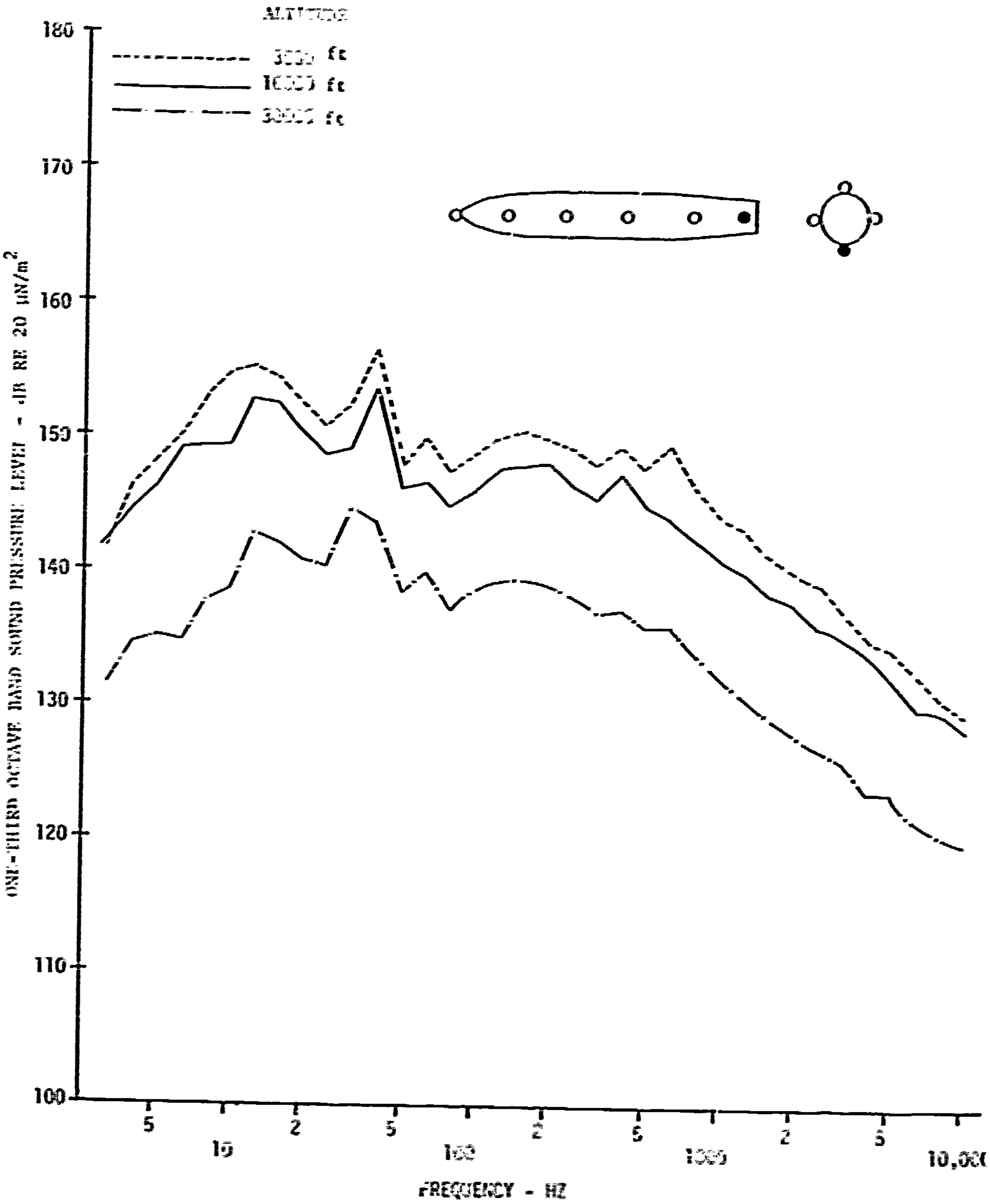


FIGURE 18 ALTITUDE EFFECT ON ONE-THIRD OCTAVE BAND SPL SPECTRA FROM MICROPHONE 19 FOR A MACH NUMBER OF 0.85

of 3,000, 10,000, and 30,000 feet from microphone locations 8, 14, and 19. The difference between the 3,000 feet and 10,000 feet data, for all three cases, is 2 to 3 dB. Also the difference between the 3,000 feet and 30,000 feet data is approximately 10 dB. This shows good scaling with altitude because the predicted differences are 2.3 dB and 9.6 dB respectively. It was concluded in Paragraph 3 of this section that the sound pressure levels, for a fixed altitude, scale well with Mach number. Thus it can now be concluded that for any altitude or Mach number the levels will scale reasonably well with q. Data from all of the other microphone locations also scaled well with the free stream dynamic pressure.

6. Equal Sound Pressure Level Contours

In order to more fully define the fluctuating pressure environment over the surface of the store, equal SPL contours were developed for various flight conditions. Figures 19 through 22 present the overall SPL contours for Mach numbers 0.8, 0.95, 1.1, and 1.3 for the 30,000 foot altitude. The longitudinal centerline in the figures represents the top of the bomb while the sidelines represent the bottom of the bomb; thus, the entire surface of the bomb can be viewed. Contours are shown for every 4 dB change in the SPL with the tics pointing in the direction of decreasing levels. The figures reveal that the intensity increases fairly uniformly for the first one-third of the store. At this point the levels become elss uniform and tend to display maximum and minimum regions. By comparing the

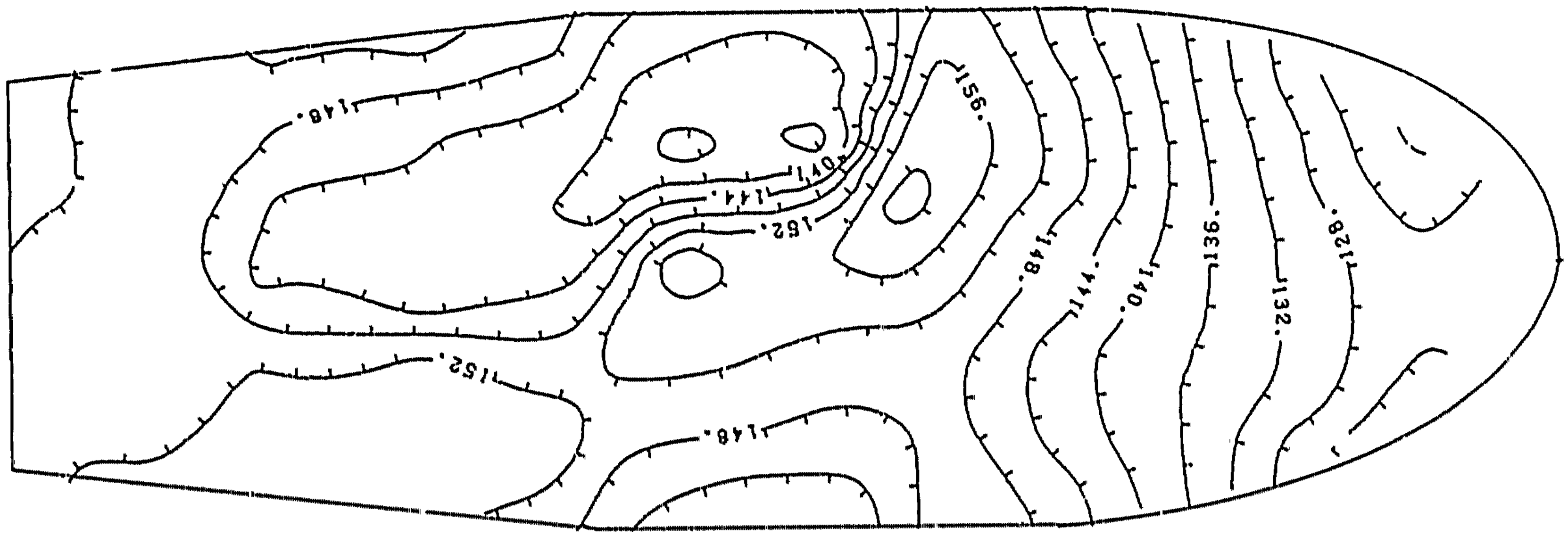


FIGURE 19 OVERALL EQUAL SOUND PRESSURE LEVEL CONTOURS FOR MACH NUMBER 0.8 AT 30,000 FOOT ALTITUDE

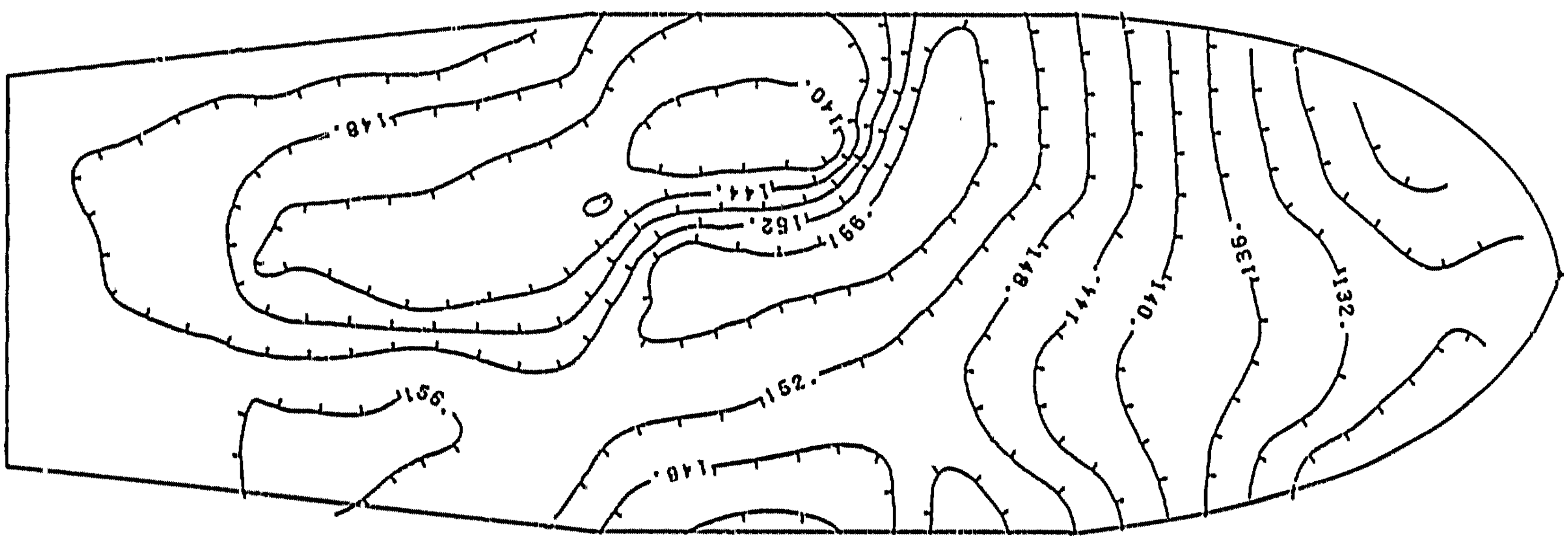


FIGURE 20 OVERALL EQUAL SOUND PRESSURE LEVEL CONTOURS FOR MACH NUMBER 0.95 AT 30,000 FOOT ALTITUDE

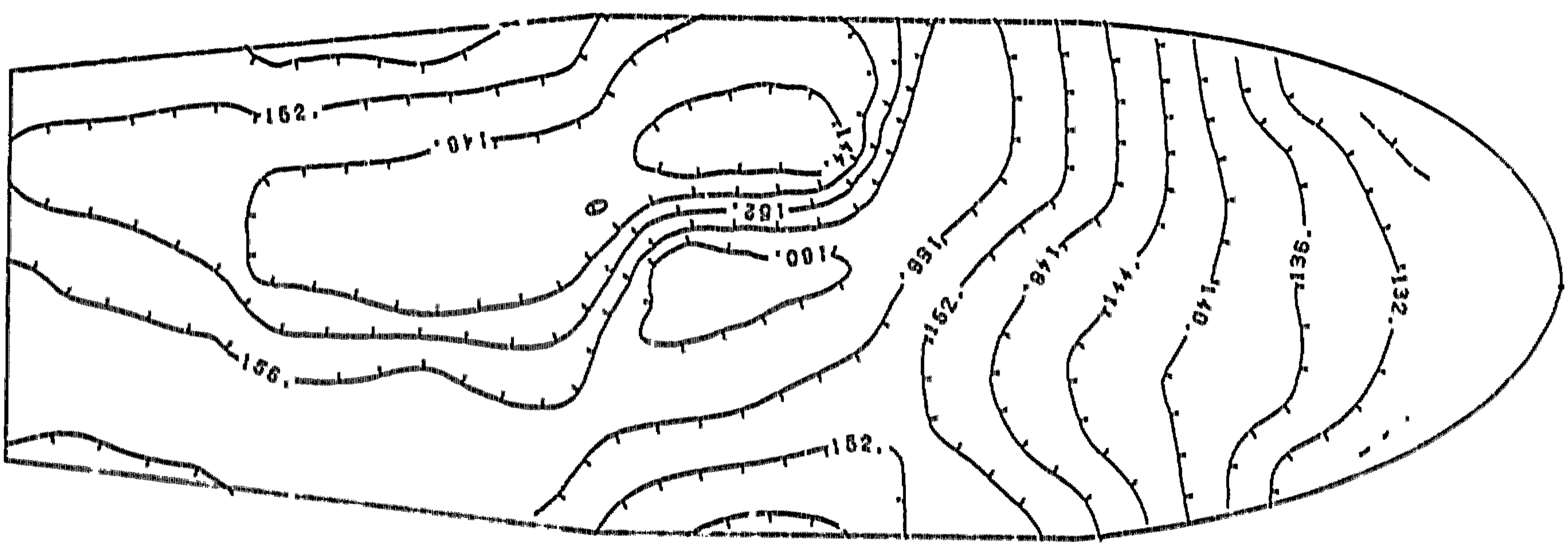


FIGURE 21 OVERALL EQUAL SOUND PRESSURE LEVEL CONTOURS FOR MACH NUMBER 1.1 AT 30,000 FOOT ALTITUDE

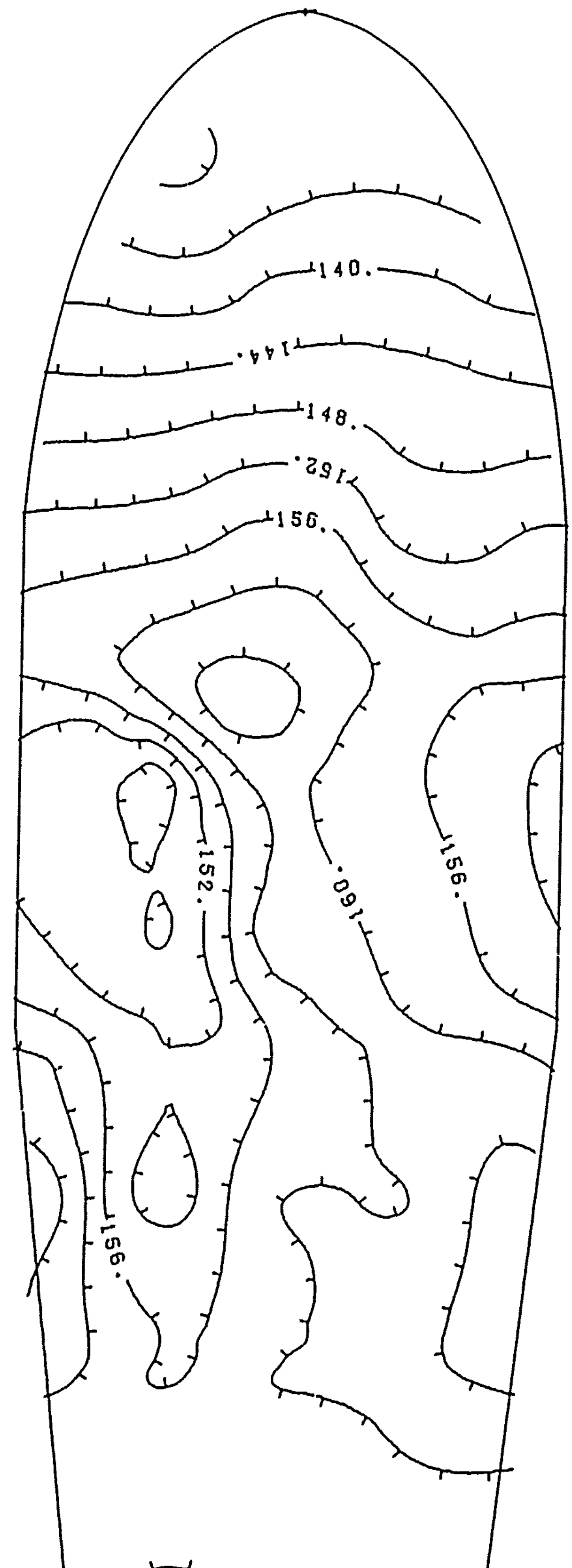


FIGURE 22 OVERALL EQUAL SOUND PRESSURE LEVEL CONTOURS FOR MACH NUMBER 1.3 AT 30,000 FOOT ALTITUDE

four figures, it appears that there are no significant variations in the contour patterns with Mach number.

Equal sound pressure level contours were also determined for the first three modal frequency amplitudes determined from the Modified Rossiter equation (see section 8). The results are shown in Figures 23 through 25 for modes 1, 2, and 3 respectively. In general there is little difference in the contour patterns for the three modal frequencies. References 3, 4, and 12-16 have shown that each modal frequency amplitude prefers a specific longitudinal mode shape, i.e., mode one displays one node, mode two displays two nodes, etc. These mode shapes were very predominate for cavities with length-to-depth (L/D) ratios of 2 to 4 but much less predominate for L/D ratios greater than 4. Since the L/D ratio of the F-111 weapons bay is greater than 7, only low amplitude mode shapes were anticipated. Since there is little difference in the contour patterns of the three modal frequencies, it is concluded that essentially no longitudinal modes existed on the surface of the store.

7. Comparison to Predicted Levels

Methods are presented in Reference 16 to predict the fluctuating pressure environment in rectangular cavities with various length-to-depth ratios for any longitudinal location in the cavities. These equations also account for variations in Mach number, altitude and modal frequency. They were used to predict the environment on the BDU-8/B and this predicted environment was compared to the measured

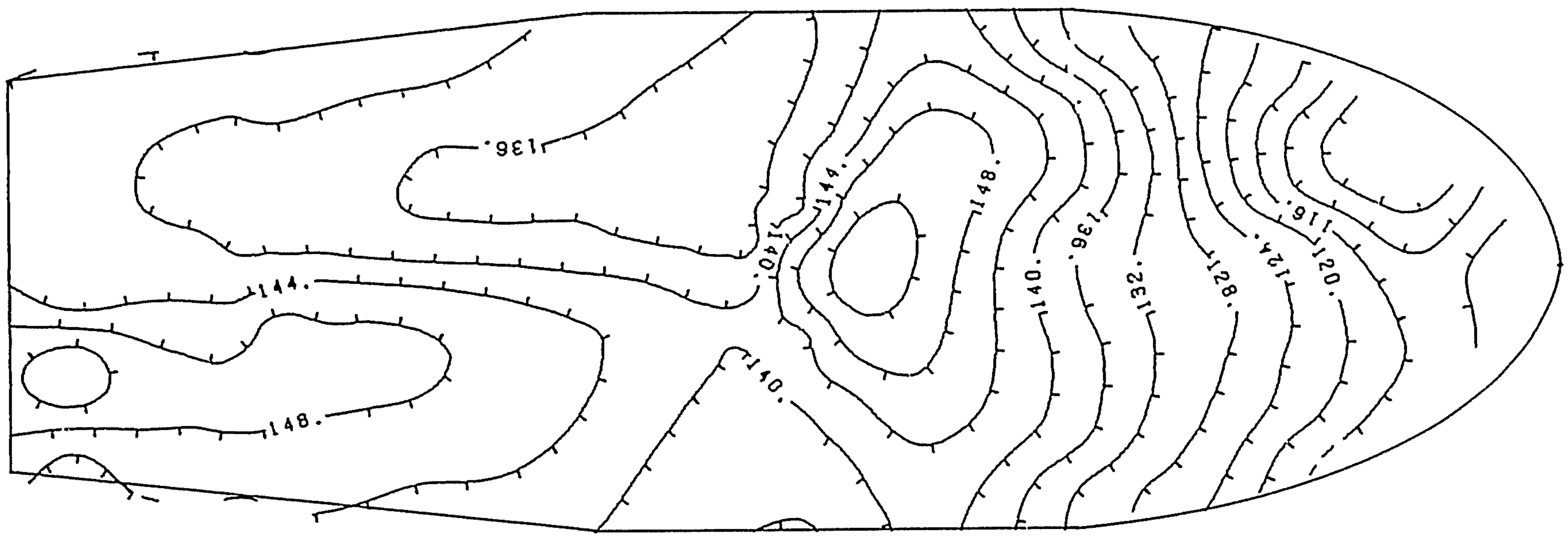


FIGURE 23 ONE THIRD OCTAVE BAND EQUAL SOUND PRESSURE LEVEL CONTOURS FOR THE FIRST MODAL FREQUENCY (16 Hz) FOR MACH NUMBER 0.9 AT 30,000 FOOT ALTITUDE

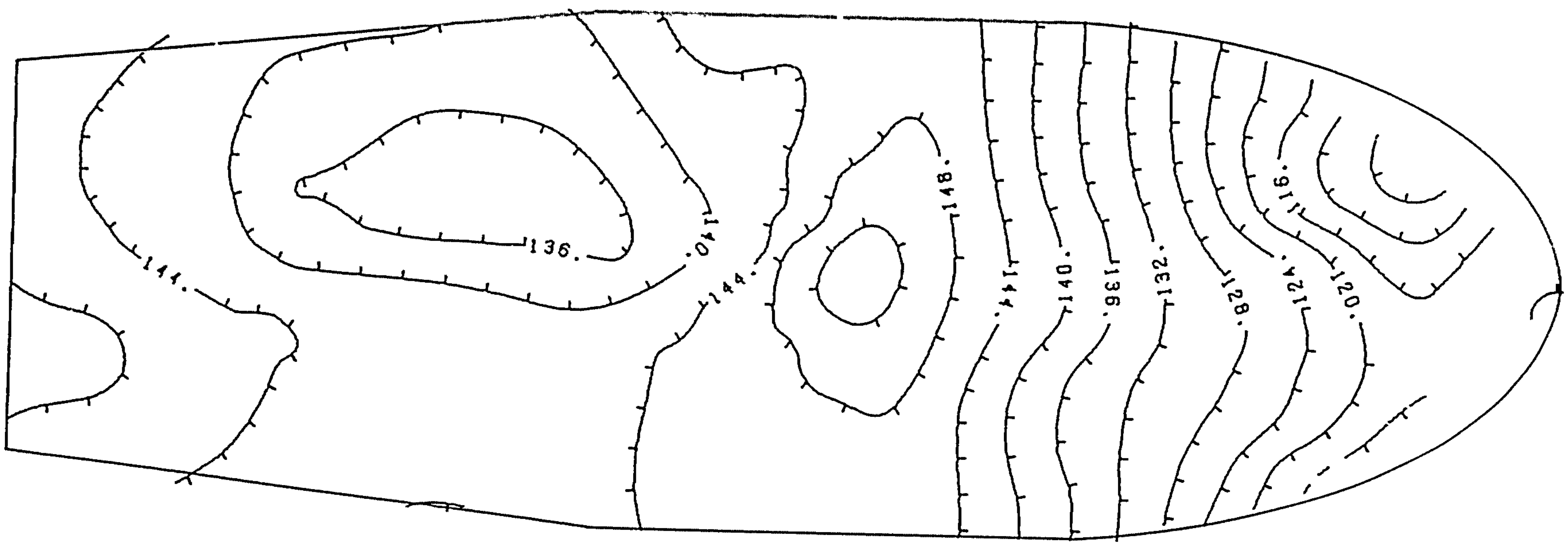


FIGURE 24 ONE-THIRD OCTAVE BAND EQUAL SOUND PRESSURE LEVEL CONTOURS FOR THE SECOND MODAL FREQUENCY (39 Hz) FOR MACH NUMBER 0.9 AT 30,000 FOOT ALTITUDE

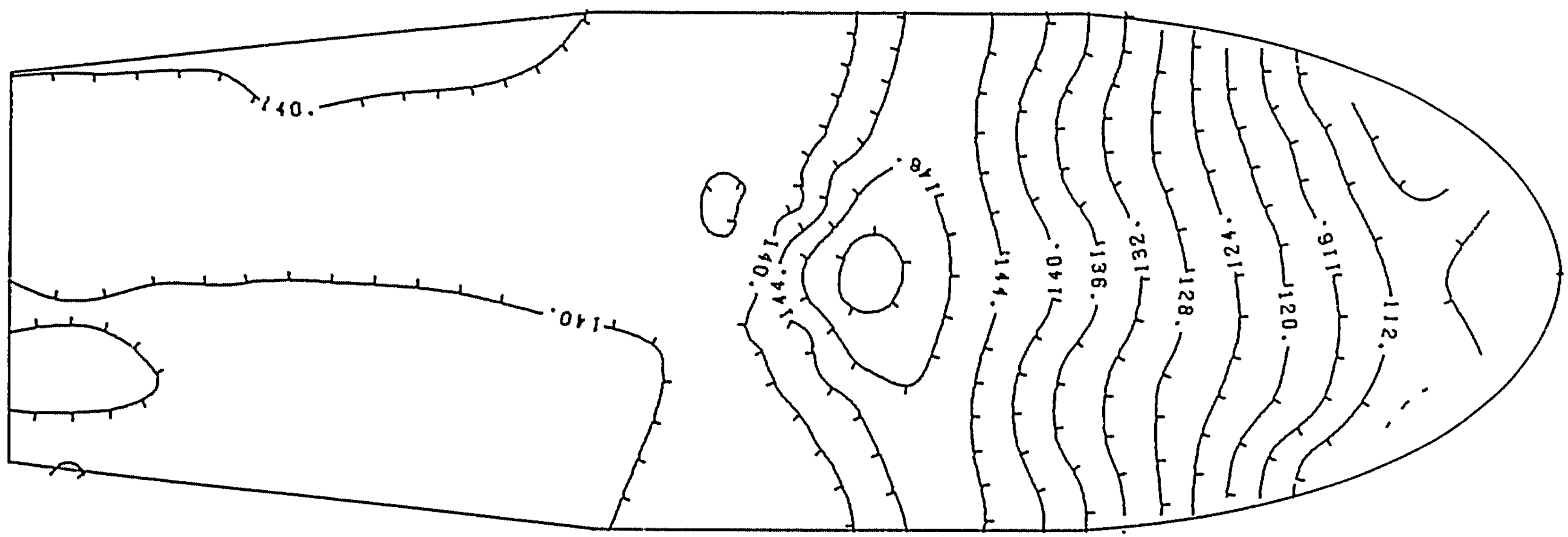


FIGURE 25 ONE-THIRD OCTAVE BAND EQUAL SOUND PRESSURE LEVEL CONTOURS FOR THE THIRD MODAL FREQUENCY (60 Hz) FOR MACH NUMBER 0.9 AT 30,000 FOOT ALTITUDE

levels. The comparisons are shown in Figures 26-28 for microphones 20, 12, and 1 respectively. Figure 26 shows that the predicted levels at the rear of the bomb agree fairly well with the measured ones falling only about 6 6o 8 dB above them for most frequencies. The data presented in Figure 27 are from the midpoint of the bomb and reveal that the predicted levels are about 15 to 20 dB too high at the lower frequencies (below 500 Hz). Figure 28 displays the data from the front of the bomb. A 20 to 25 dB difference between the measured and predicted levels exists at this location. These figures indicate a trend of decreasing agreement between the predicted and measured levels from the rear to the front of the bomb. An explanation for this trend was given in section 2, "Mach Number Variation" where it was shown that the full scale flight data tends to show larger decreases in the SPL from the rear to the front than the predicted ones possibly because (1) the scaling effects of the cavity influence the variation in levels, and (2) the full scale cavity is normally cluttered as compared to the research cavities. Also, the predictions were based on data obtained from the wall of the cavities while the present data were obtained from the surface to the store.

8. Narrowband Spectra

Narrowband analysis was performed on selected data from every microphone. Spectra were obtained over the Mach number range of the test at each of the three altitudes. The analysis was performed up

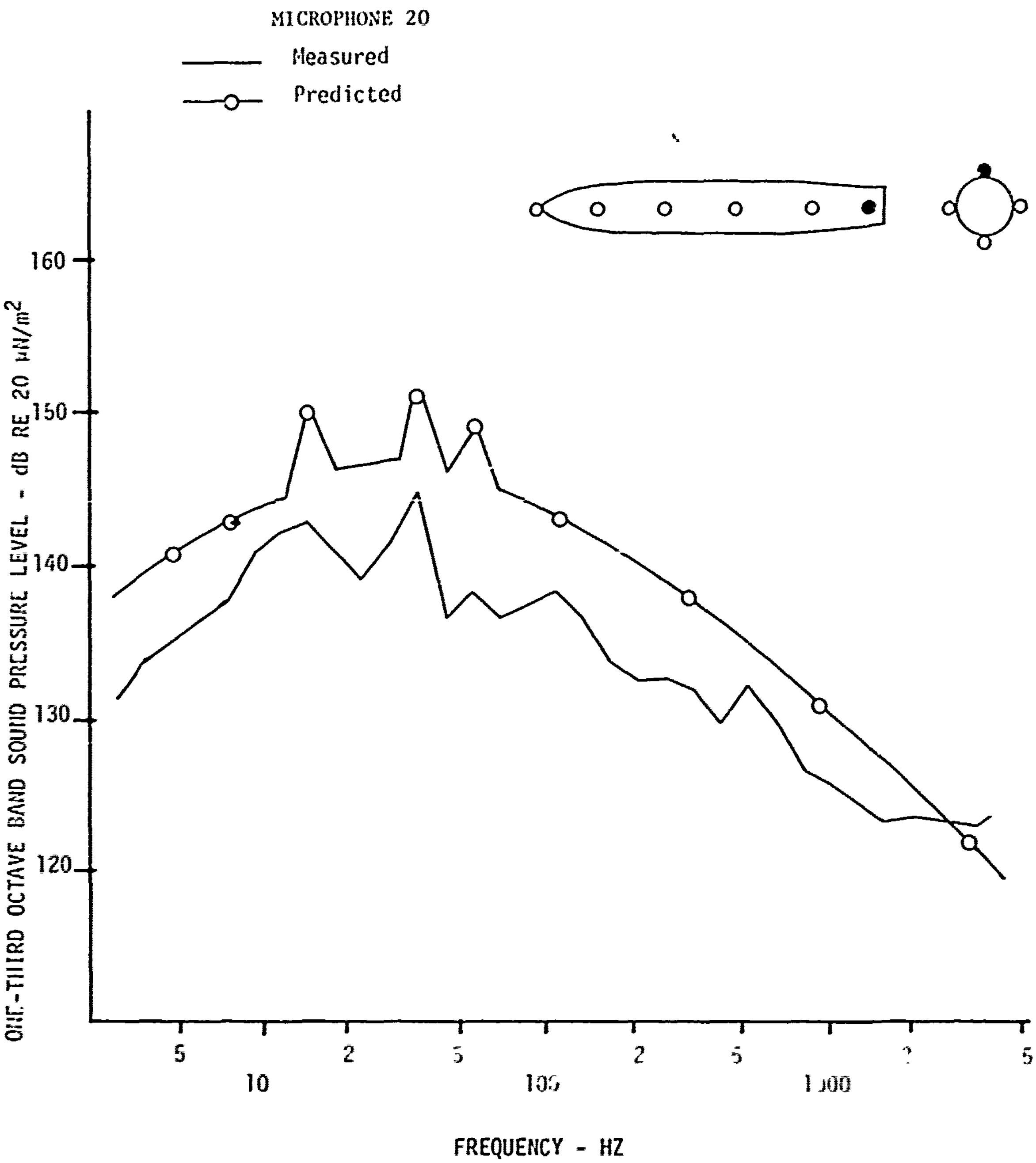


FIGURE 26 COMPARISON OF THE PREDICTED AND MEASURED SPECTRA FROM THE FRONT OF THE BOMB FOR MACH NUMBER 0.9 AT 30,000 FOOT ALTITUDE

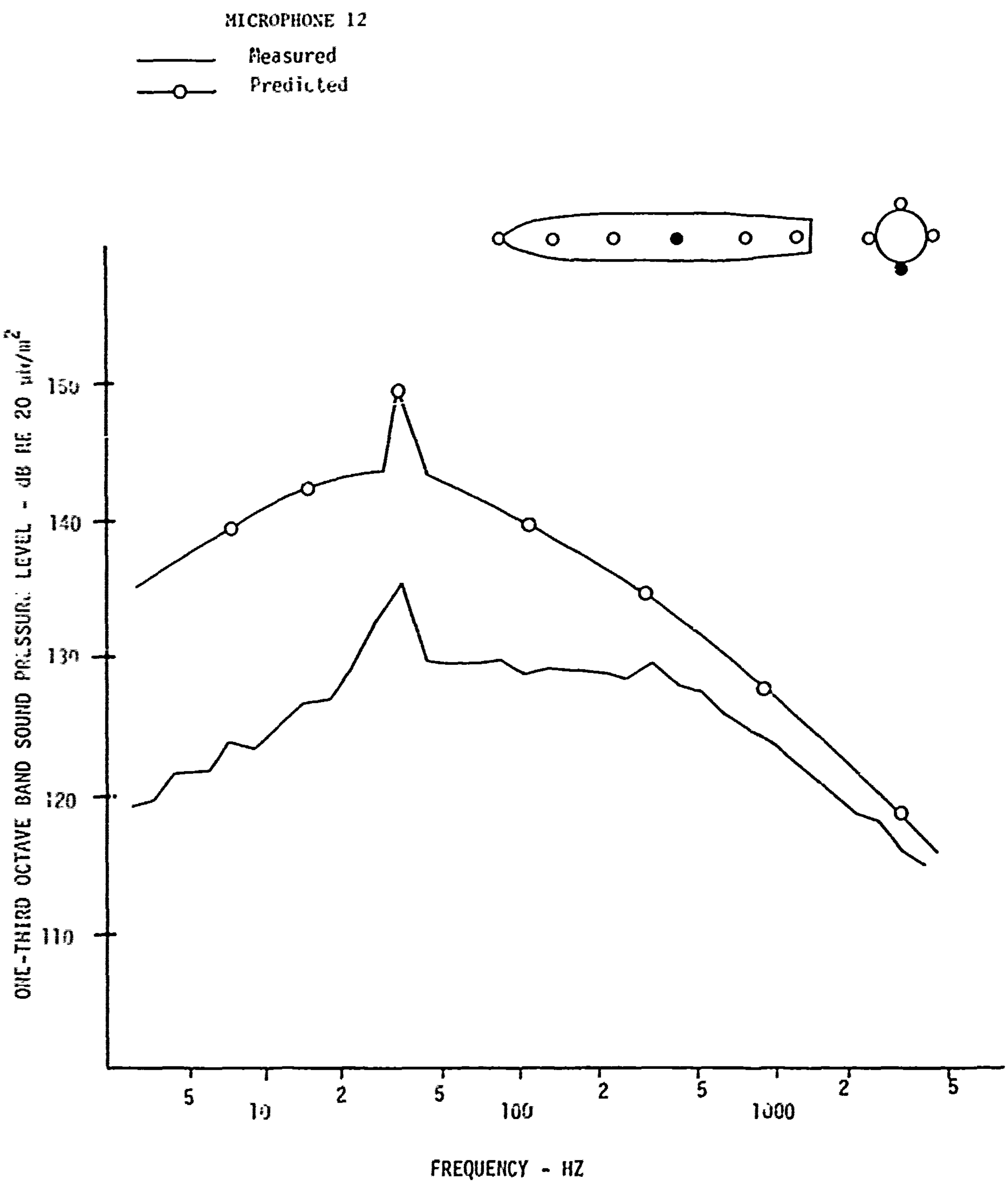


FIGURE 27 COMPARISON OF THE PREDICTED AND MEASURED SPECTRA FROM THE MIDDLE OF THE BOMB FOR MACH NUMBER 0.9 AT 30,000 FOOT ALTITUDE

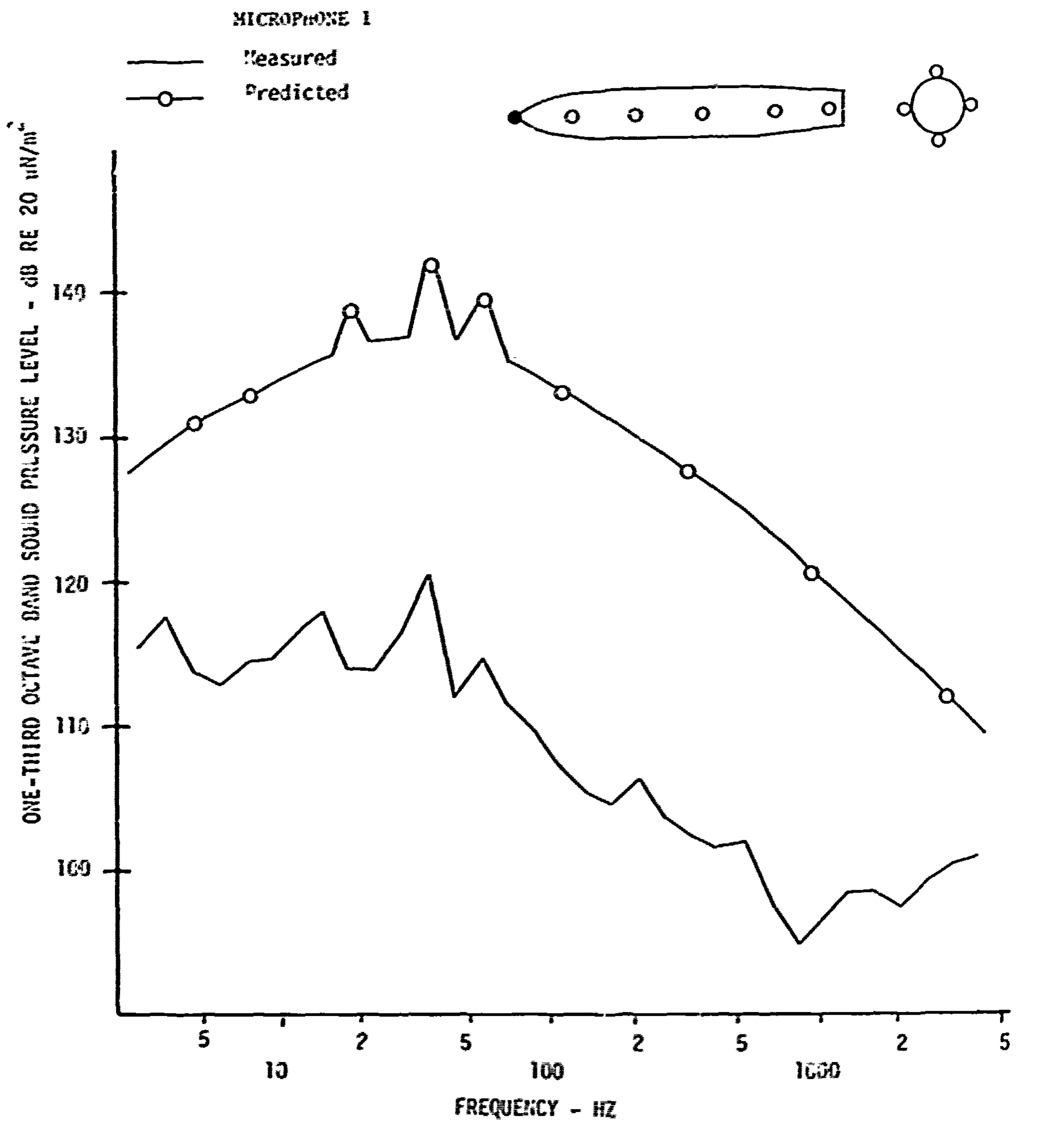


FIGURE 28 COMPARISON OF THE PREDICTED AND MEASURED SPECTRA FROM THE FRONT OF THE BOMB FOR MACH NUMBER 0.9 AT 30,000 FOOT ALTITUDE

to 5000 Hz but only data up to 120 Hz are presented since there was no significant energy above that frequency.

Figures 29, 30, and 31 present the narrowband spectra for microphones 1, 8, and 20 respectively. These data are typical for most of that analyzed. Most of the energy is located in the low frequencies, the modal frequencies of the cavity. These frequencies are predicted by the modified Rossiter equation

$$f = \frac{V}{L} \; \frac{m - 0.25}{\frac{M}{(1 + .2M^2)^{1/2}} + 1.75}$$

where V is the freestream velocity, L is the cavity length, M is the freestream Mach number and m is the modal frequency number. The predicted first three modal frequencies show very good agreement with this equation.

9. Comparison to Past Data

In 1967, a flight test was performed on an F-111 aircraft with a Phoenix missile installed in the weapons bay. Limited acoustic data were obtained on the surface of the missile. The results of the test are documented in Reference 15.

The acoustic data were acquired from two microphones. One microphone was located on the forward section of the missile in about the same location as microphone 8 on the store used in this test.

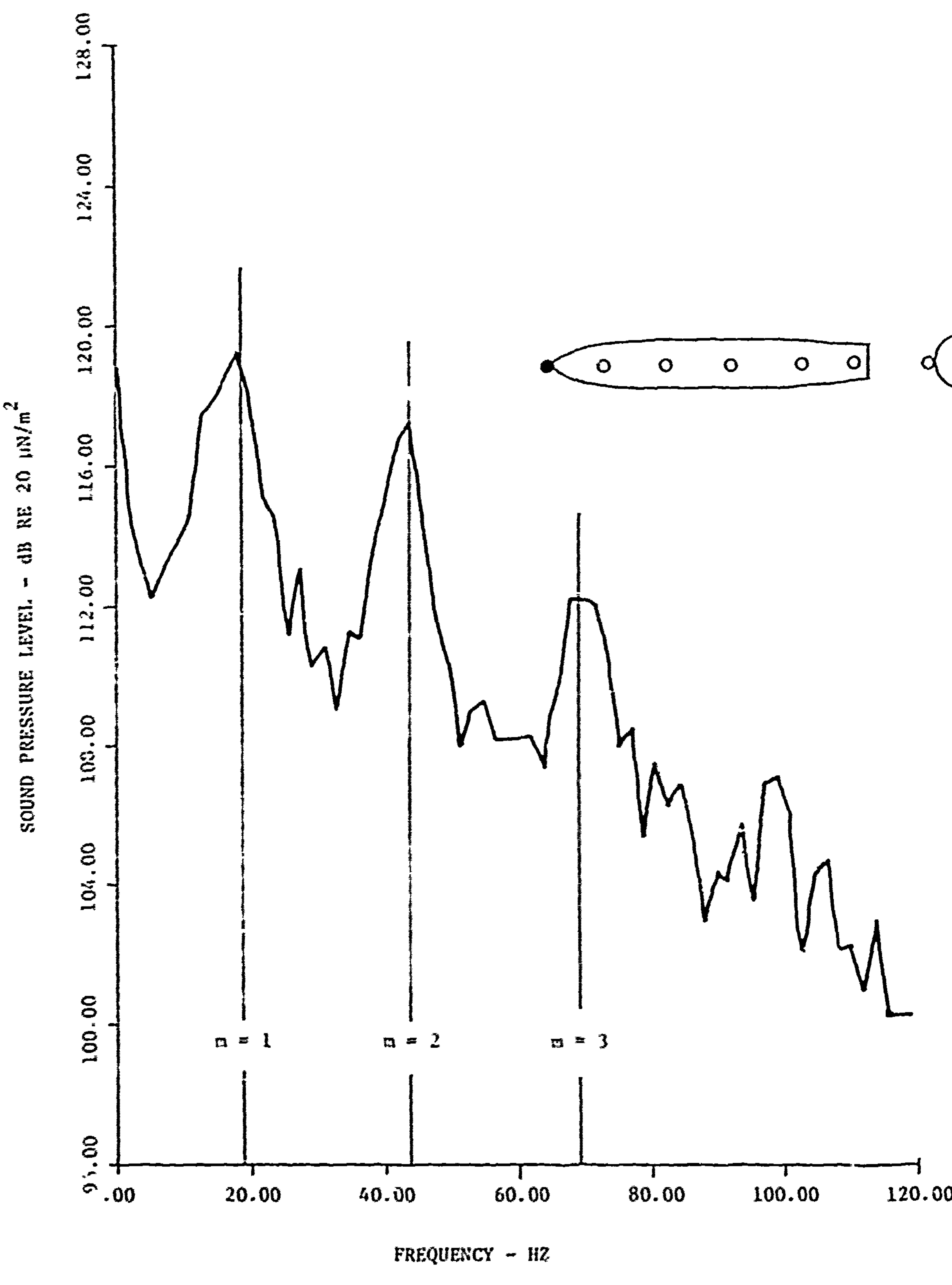


FIGURE 29 NARROWBAND SPECTRA FROM MICROPHONE 1 FOR 1.1 MACH NUMBER AND 30,000 FOOT ALTITUDE

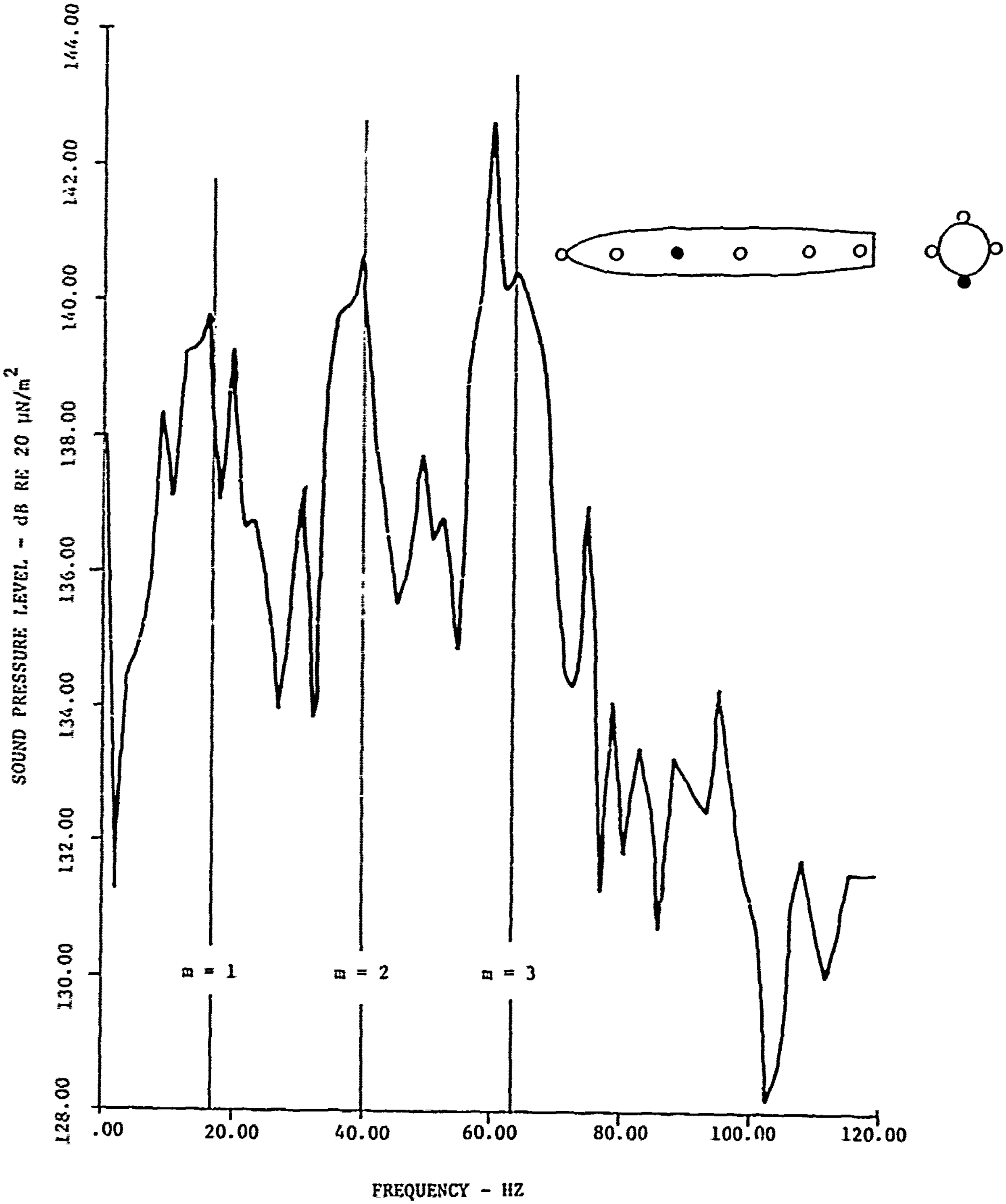


FIGURE 30 NARROWBAND SPECTRA FROM MICROPHONE 8 FOR 0.85 MACH NUMBER AND 30,000 FOOT ALTITUDE

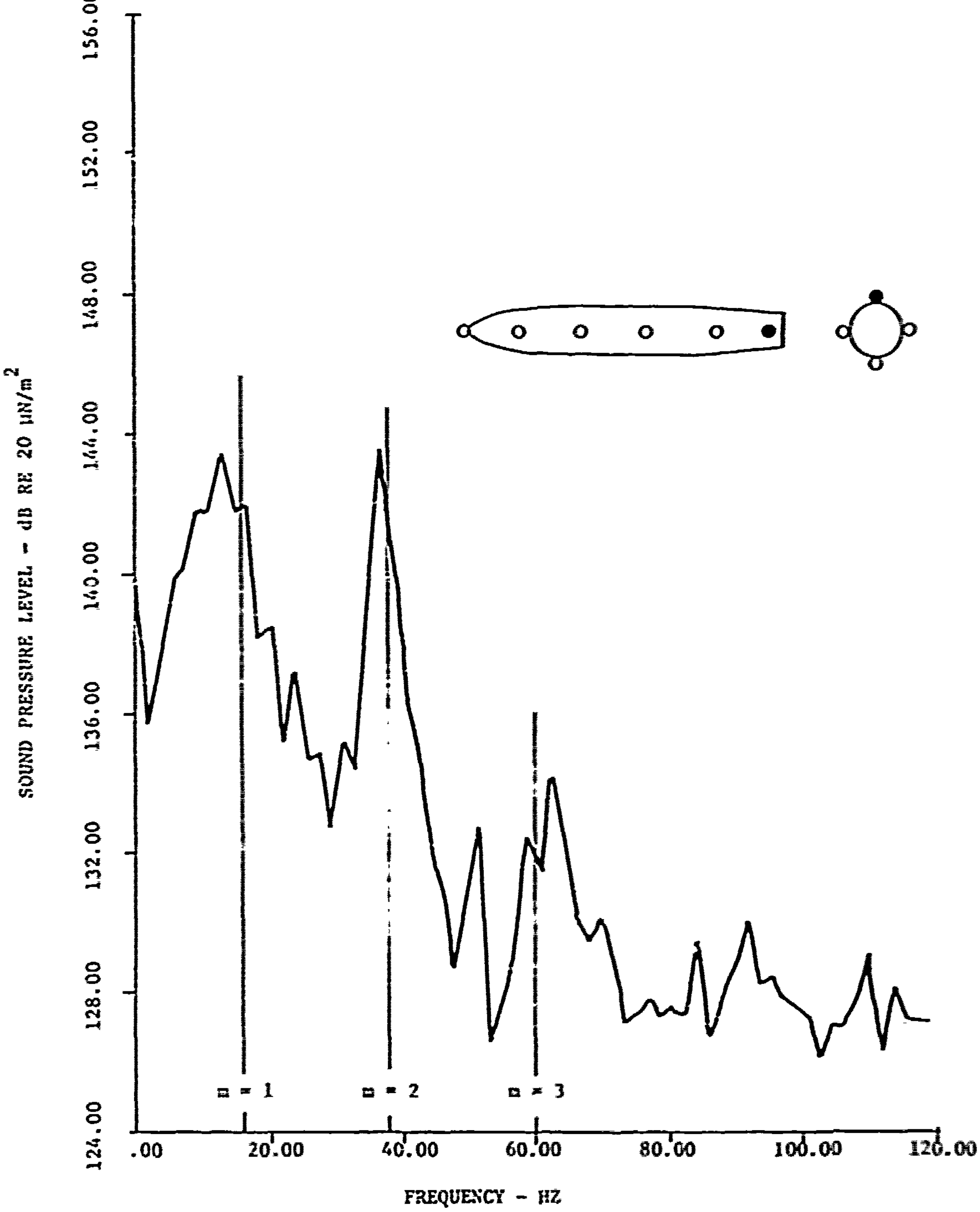


FIGURE 31 NARROWBAND SPECTRA FROM MICROPHONE 20 FOR 0.9 MACH NUMBER AND 30,000 FOOT ALTITUDE

The other microphone was located towards the rear of the missile near the location of microphone 18 from this test. In this study the store was installed in the left side of the weapons bay while the Phoenix was located on the right side. The present data indicated that there are variations in the acoustic environment from side to side when the store is asymmetrically installed. Thus, to eliminate this source of difference, data from microphone 17, which was on the opposite side of the store, was compared to the Phoenix data. Microphone locations are shown in Figure 2.

The data are compared on a power spectral density basis and the results are shown in Figures 32 and 33. Figure 32 shows the comparison of the data from the front of the stores. The data are for a Mach number of 0.85 and an altitude of 3,000 feet and 2,000 feet for the current store and Phoenix missile respectively. The cavity excited frequencies are clearly evident for the EDU-8/B but are much less obvious for the Phoenix missile. Also, the Phoenix data appear to be 4-5 dB higher than the current data for all frequencies below 1,000 Hz except for the cavity excited frequencies. Comparison of the data at the rear of the stores is shown in Figure 33. The EDU-8/B data are for a Mach number of 0.9 and the Phoenix are for the 0.97. The altitudes are 30,000 feet and 36,776 feet respectively. The differences in the data for the rear of the stores are very similar to that at the front. The cavity excited frequencies are seen to vary somewhat for each store. The variation is largest for the lowest frequency. However, considering that these

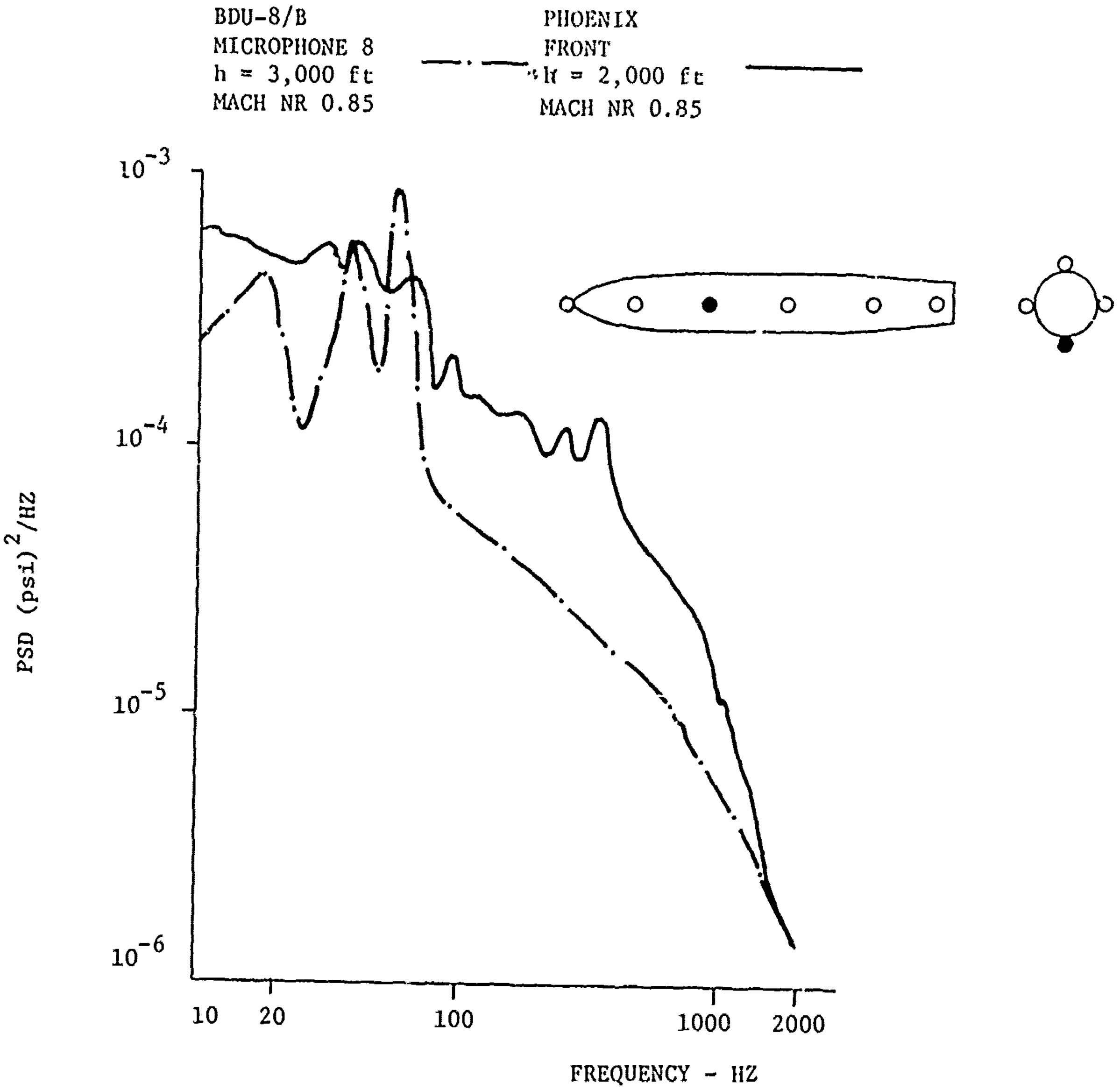


FIGURE 32 COMPARISON OF BDU-8/B DATA TO THE PHOENIX DATA FOR THE FORWARD LOCATION

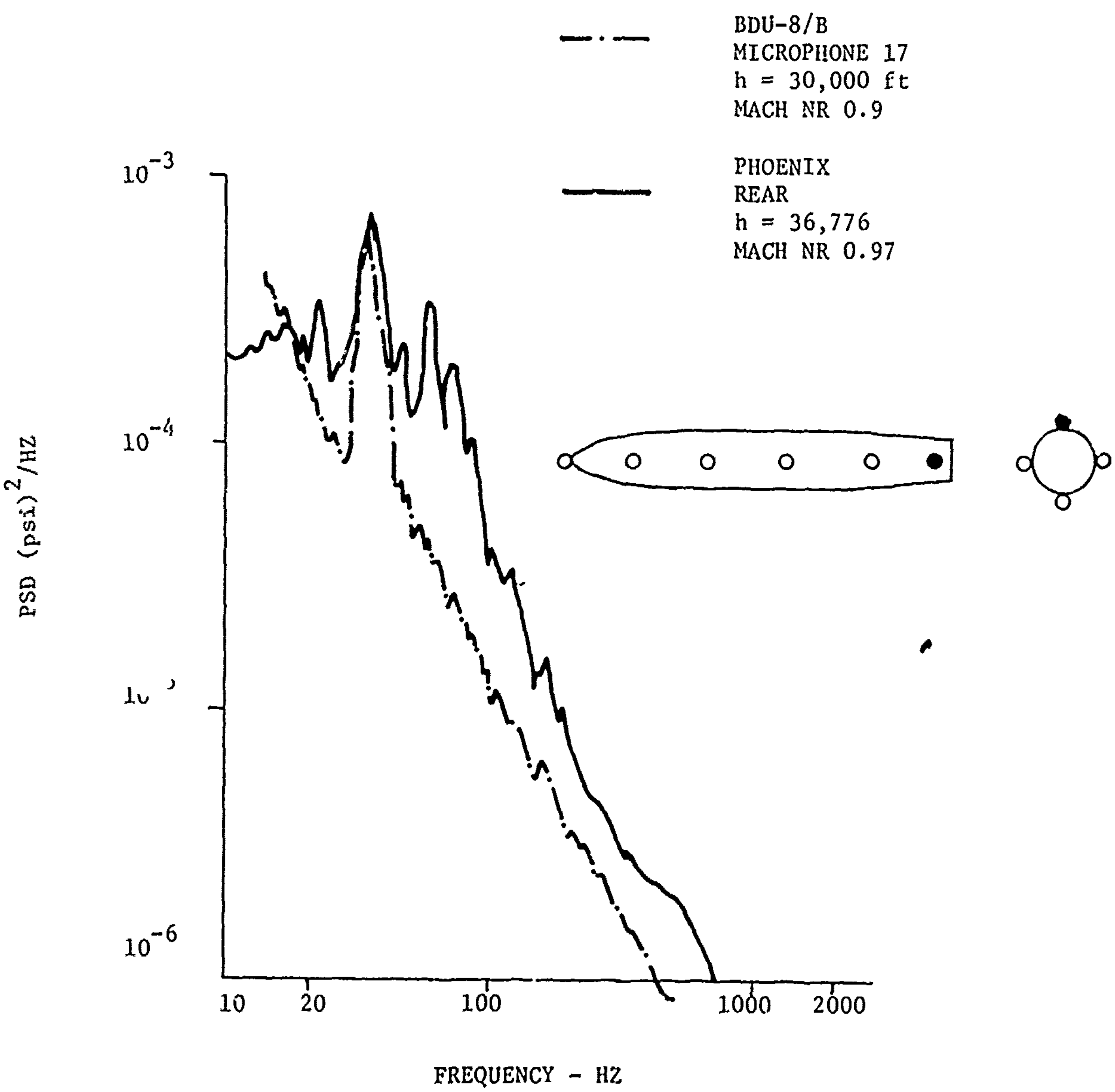


FIGURE 33 COMPARISON OF BDU-8/B DATA TO THE PHOENIX DATA FOR THE AFT LOCATION

are two independent flight tests with different stores, the data show good agreement.

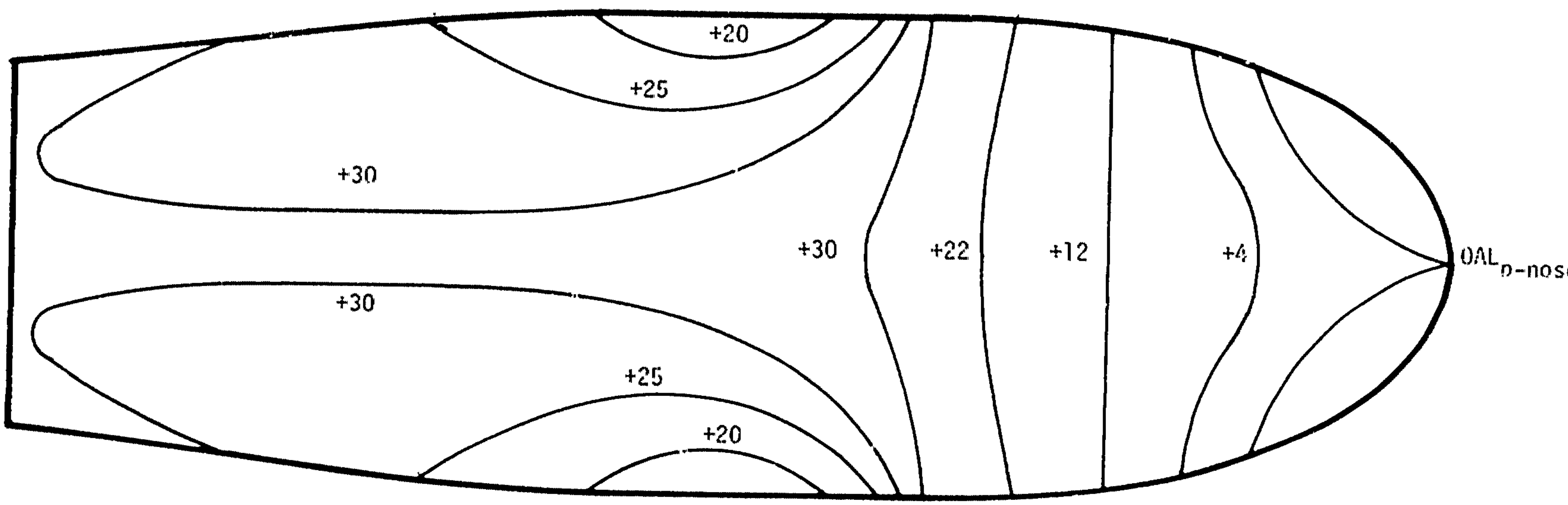
SECTION IV

ENVIRONMENT SIMULATION

It is desirable to simulate the in-flight fluctuating pressure environment of a store in an acoustic test chamber. This would permit the performance of vibration qualification tests on the store's sensitive internal equipment. In order to conduct such tests, the fluctuating pressure distribution over the surface of the store is needed for any given flight conditions. This section offers a method to obtain these distributions.

Figures 19 through 25 presented equal sound pressure level contours over the surface of the bomb for various flight conditions. For the purpose of simulation the trends in these figures are summarized in Figure 34.

It should be kept in mind that the entire surface of the bomb is shown in the figure, that is, the bomb was unwrapped. The centerline represents the top of the bomb and the side lines are the bottom. The major trends are an increase in the overall sound pressure level from the nose back to about the one-third position on the bomb. From that position the levels remain fairly constant along the top to the rear of the bomb. However, the levels along the bottom decrease 10 dB and then increase the same amount towards the rear. The sound pressure level at the nose varies with Mach number and altitude, that is, the free-stream dynamic pressure. A normalized expression which considers these variations was found to be



10 log (P_{nose}/q) = -35 dB

FIGURE 34 VARIATION OF THE EQUAL SOUND PRESSURE LEVEL CONTOURS WITH MACH NUMBER AND ALTITUDE

$$10 \log(P\ \text{nose}/q) = -35\ \text{dB}$$

where q is the freestream dynamic pressure and P is the overall rms sound pressure at the nose of the bomb. Using this expression and the equal sound pressure contour, the absolute overall levels on the entire surface of the bomb can be determined. For a complete definition of the environment, the spectrum shape of the surface pressures must be known. An average one-third octave band spectrum shape was derived from the measured data and is shown in Figure 35 where the levels are references to the overall level. This spectrum shape is recommended for the entire surface of the bomb.

With knowledge of the overall levels, surface distributions and spectrum shape the complete environment can be simulated in an acoustic test facility and reliable vibration qualification tests can be performed.

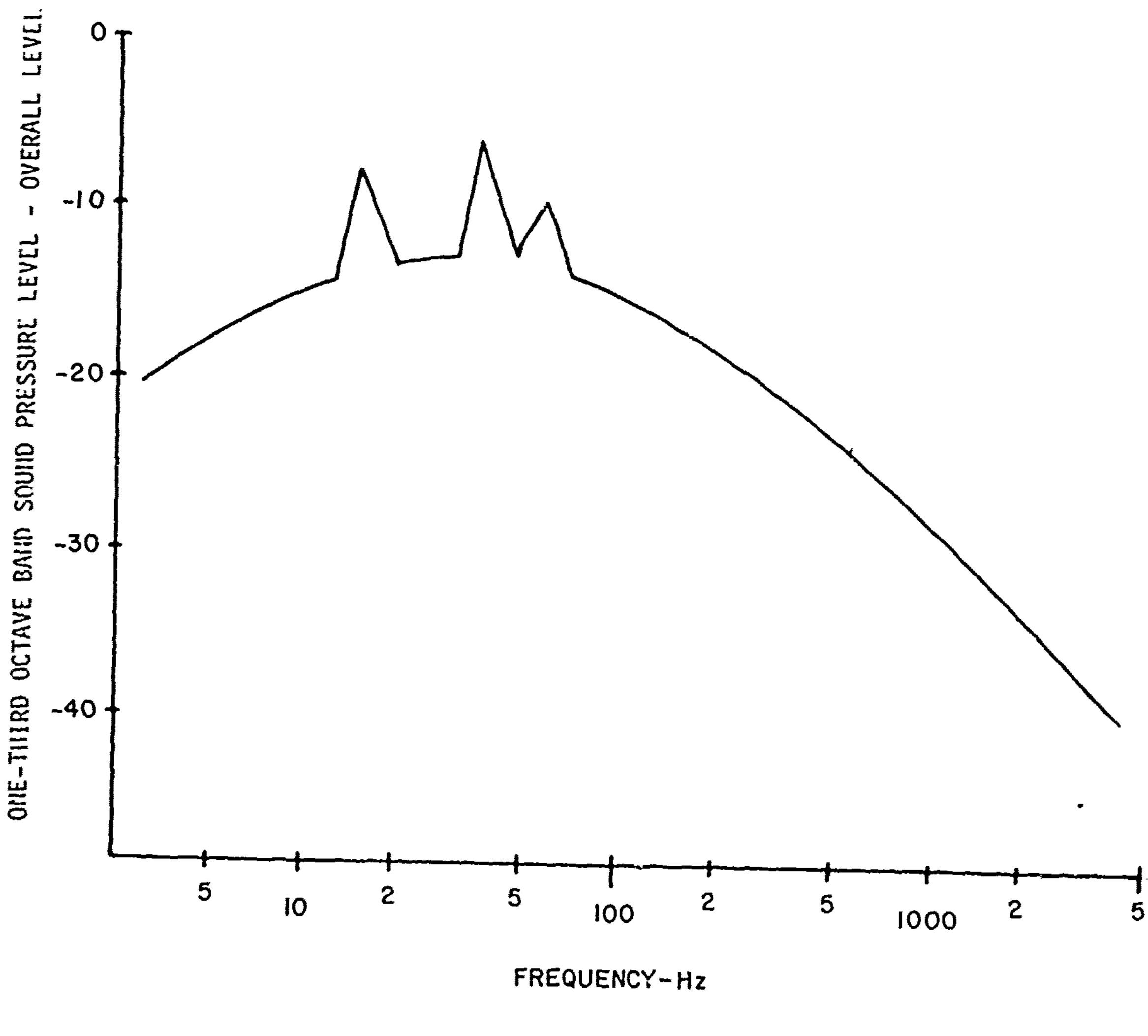


FIGURE 35 ONE-THIRD OCTAVE BAND SPL SPECTRUM RECOMMENDED FOR ENVIRONMENT SIMULATION

SECTION V

SUMMARY OF RESULTS

The principle results determined from the flight tests are summarized as follows:

1. The fluctuating pressure levels on the surface of the bomb scale well with freestream dynamic pressure, that is, with Mach number/altitude pressure.

2. The levels on the surface of the bomb increase from the front to the rear by about 30 dB.

3. Predictions resulting from the methods in Reference 13 compare well to the measured levels on the rear of the bomb but vary significantly towards the front.

4. There are significant circumferential variations in the levels on the surface at several longitudinal locations.

5. The equal fluctuating pressure level contour for the surface of the bomb vary only a small amount with changes in Mach number or modal frequency.

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